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JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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American Welding Society

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AMERICAN WELDING SOCIETY
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Volume 4 September, 1925 Number 9

Program
Fall Meeting
American Welding Society

October 21, 22 and 23, 1925

Headquarters

Technical sessions, exhibitions, demonstrations—*Massachusetts Institute of Technology.* **Social functions, dinner, sightseeing trips**—*Hotel Somerset,* Commonwealth Avenue, Boston.*

Exhibitions and Demonstrations

Exhibitions and demonstrations will be open on each day of the meeting, Wednesday, Thursday and Friday, from 9 a. m. to 5 p. m., and on Wednesday evening at 7.30 p. m. to 9.00 p. m.

Sight Seeing Buses

Those who have never before been in Boston will be provided with an opportunity of visiting its many historic points of interest by means of sightseeing buses. Buses will start at the hotel and visit points of interest in and around Boston, Concord and Lexington and North and South Shore Drives. No charge will be made for the ladies on these trips. For full information apply at registration desk.

Lunches

For the convenience of members and guests, lunches will be served at cost on each day at the cafeteria of the Massachusetts Institute of Technology.

*Note: The rates for single rooms with bath are $5 to $7 per day, double room with bath $6 to $10 per day. Members and guests should make arrangements for their accommodations with the hotel. Hotel Somerset was selected because of its accessibility to the exhibits and meetings of the Society at M. I. T.

Dinner and Theater Party

An informal banquet will be held on **Thursday evening, October 22, at the Hotel Somerset.** Tickets for the banquet ($5.00 each) should be reserved in advance if possible. No charge will be made for the ladies. The music and speeches will be broadcasted by radio station WNAC, Shepard Stores, Massachusetts, at a wave length of 280 meters. The program is as follows:

Music from 5.30 to 6 p. m. Dinner from 6 to 7.15 p. m. Speeches from 7.15 to 8 p. m.

The speakers will include Mayor Curley of the City of Boston, Dr. S. W. Stratton, President of the Massachusetts Institute of Technology, Prof. C. A. Adams, Founder of the Society and Director of the American Bureau of Welding, Prof. Elihu Thomson of the General Electric Company and Prof. A. S. Kinsey of Stevens Institute.

Arrangements have been made for a theater party to see **"The Student Prince"** at the Shubert Theater immediately after the banquet. Motor buses will convey the members and their guests from the hotel to the theater. Theater tickets at $3.30 each may be reserved in advance by writing direct to Mr. J. W. Morrissey, Secretary of the Boston Section, care of P. F. McDonald & Co., 17 King Terminal, Boston, Mass. No charge will be made for the ladies.

PROGRAM

WEDNESDAY, OCTOBER 21, 1925

Morning

10 a. m. to 12 m. **Room 5-330**

"Thermit Welding," J. H. Deppeler, Chief Engineer, Metal and Thermit Corporation.

Afternoon

2 p. m. to 4 p. m. **Room 5-330**

"Gas Welding of Power Plant Piping," A. W. Moulder, Chief Engineer of the Grinnell Company.

Evening

7:30 p. m.

Special exhibition and demonstration of welding and cutting applications.

THURSDAY, OCTOBER 22, 1925

Morning

10 a. m. to 12 m. **Room 3-270**

"Industrial Applications of Arc Welding and Economies Effected Through Its Use." Joint paper by H. M. Hobart, Chairman, Electric Arc Welding Committee, and W. Spraragen, Secretary.

Afternoon

2 p. m. to 4 p. m. **Room 5-330**

Meeting of American Bureau of Welding. (Research Department of Society.) Program will include review of present activities and outline of future investigations.

Afternoon

4 p. m.

Meeting of Board of Directors of the American Welding Society.

Evening

5:30 to 8 p. m.

Dinner party. **For details see page 2.**

8 p. m.

Theater party. **For details see page 3.**

FRIDAY, OCTOBER 23, 1925

Morning

10 a. m. to 12 m. **Room 5-330**

"Selection of Materials for Welding." A series of short addresses by several prominent experts on this subject.

"Welding Wire a Factor in Good Welding," C. A. McCune, Director of Research, American Chain Company; "Weldability of Ferrous Metals," C. J. Holslag, Chief Engineer, Electric Arc Cutting and Welding Co.; "Selecting Welding Wire," L. Oliphant, Oxweld Acetylene Co.; "High Strength Welds," J. R. Dawson, Union Carbide and Carbon Research Laboratories.

Afternoon

2 p. m. to 4 p. m. **Room 3-370**

"Manufacture of All Steel Automobile Bodies" (illustrated by moving pictures). J. W. Meadowcroft, General Supervisor of Welding, E. G. Budd Manufacturing Company.

FALL MEETING

The greatest fall meeting of the society has been planned for this year and will be held in Boston. Details, including complete program, are given elsewhere in this issue. This fall meeting can only be the success which the officers have planned for it if it has the cooperation of all the local sections and members of the society. Over 20,000 guests will be invited to this meeting. It is imperative that we have proper representation of our own members. In order to facilitate arrangements, cards will be sent to all the members of the society in advance, which should be filled in and returned promptly.

PRESSURE VESSEL INVESTIGATIONS

At a conference held in New York on Sept. 11, under the auspices of the American Bureau of Welding (research department of the society), a number of tank manufacturers were informed as to the plans of the Bureau to carry out a comprehensive investigation in the field of welded pressure vessels.

Welding experts have conceded that the present code of the A. S. M. E. is unduly restrictive in its requirements for welding. The Bureau, through a pressure vessel committee, intends to cooperate with the A. S. M. E. in bringing about suitable modifications in these rules.

Prof. C. A. Adams, director of the bureau, has divided the work into two phases:

1. Modifications in the rules which can be requested on the basis of existing evidence.
2. The carrying out of a comprehensive investigational program to secure information and data now lacking.

The manufacturers present concurred with the plans of the bureau and pledged their support to carry out a $120,000 investigation in this field. Actual cash contributions will, of course, be a much smaller sum of the order of $15,000. Tanks, materials, test specimens and testing facilities will make up the remainder of the sum mentioned above. Work will be started as soon as the funds are in the hands of National Research Council, which organization has agreed to act as treasurer of the fund.

Prof. H. L. Whittemore of the Bureau of Standards has been selected as chairman of the Pressure Vessel Committee, which will have the work in its immediate charge. Most of the testing will be done at the Bureau of Standards.

A temporary pressure vessel committee, appointed by Professor Adams, has prepared a statement covering the modifications of the code, which should be brought about on the basis of existing evidence. This statement, together with a letter of transmittal to Secretary Obert of the committee, is reproduced below.

Sept. 14, 1925.

Mr. C. W. OBERT, Secretary,
Boiler Code Committee, A. S. M. E.,
29 West Thirty-ninth Street,
New York City.

Dear Mr. OBERT:

On Jan. 13, 1925, President E. H. Ewertz of the American Welding Society wrote you to the effect that while the present code for unfired pressure vessels is unsatisfactory in its restrictions and incomplete in its provisions as far as it relates to fusion welding that we welcome the work of your committee as an initial step in the right direction and as a basis for future adjustment.

On Jan. 22 you advised us that this expression of opinion was appreciated by your committee, that you would welcome our cooperation in the future and that your committee would at all times give careful consideration to communications received from us.

At a meeting of the American Bureau of Welding in April, Dr. D. S. Jacobus stated that the A. S. M. E. Boiler Code Committee were anxious to cooperate with us in every way possible.

As director of the American Bureau of Welding, I appointed a pressure vessel committee and instructed them:

1. To go over the present code of the A. S. M. E. and to select the more important rules that in their opinion were unduly restrictive and to suggest modifications of these rules, each modification to be accompanied by sufficient evidence to show that the change was desirable.

2. I also instructed the committee to outline a program of additional tests and investigations needed to secure further information and data now lacking.

You will find attached to this letter a report of the findings of this committee which I trust will receive your careful consideration. This commit-

tee will be glad to meet with you at any time upon proper notice.

You will notice that the program of investigational work is aimed at securing information which will form the basis for extension of the code to include lap welded seams, single V seams welded from one side and from two sides, and also automatically welded tanks.

Our committee also hopes at some time in the near future to bring to you a suggested appendix to the code covering inspection of welding and finished products and tests for checking the skill of welding operators.

Yours very sincerely,
C. A. ADAMS, Director.

PROPOSED MODIFICATIONS A. S. M. E. RULES ON FUSION WELDING OF UNFIRED PRESSURE VESSELS

Maximum Unit Fiber Stress

The code restricts the maximum unit working fiber stress to 5600 pounds per square inch, in Section U68.

In Bulletin No. 5 of the American Welding Society describing the tests made at the Bureau of Standards in Washington, it is recommended that a maximum unit working stress of 8000 pounds be allowed on longitudinal double vee welded seams. This is based on 50,000-pound plate, a factor of safety of 5, and a weld efficiency of 80 per cent. The present committee believes that these figures are very conservative, because the lowest efficiency of any double vee weld in the tests at the Bureau of Standards was 90 per cent.

We would also call attention to the tensile shock tests reported in Bulletin No. 5 on page 36, the explanation of the method of test being given on page 32 and following. It will be noticed that these tests simulate those made on the actual tanks, the test piece being struck while under load in the testing machine with a pendulum hammer of suitable weight. All of the double vee welds broke outside the weld, no defects being visible in or near them, and the tensile strength of pieces tested in this way showed the same strength as straight tensile tests of unwelded pieces within very close limits.

There were also made some flattening tests of pieces that had been welded together at an angle, which are presented in Bulletin No. 5 beginning on page 39. In these tests no injury was caused to the welds where they were of the double vee type.

In view of the above facts, the committee recommends that a maximum unit working fiber stress of 8000 pounds per square inch of plate section be allowed in the code for double vee welds.

Maximum Diameter

The Unfired Pressure Vessel Code restricts the use of longitudinal seams to vessels of a maximum diameter of 20 in. The committee does not see any engineering reason why a longitudinal seam in a 40-in. tank, for example, is any more dangerous than one in a 20-in. tank. There is no limit to diameter in the case of rivited, forge welded, or brazed tanks in the pressure vessel code. If it is considered good engineering to allow any diameter in the case of these three methods of joining, it is equally good engineering to allow it in the case of welding.

The Heating Boiler Code is a precedent for allowing much larger diameters than 20 in. in welded construction. Heating boilers for steam operating at pressure not exceeding 15 pounds per square inch may, according to the code, be of any diameter at all and may be of either riveted or welded construction, and there is specific authority for making them over 78 in. in diameter. (See Table H1, giving the minimum allowable thickness of shell plates for different diameters.)

Of course, it is understood that the thickness of the shell for a large diameter steam heating boiler is required to be so great that the working fiber stress is very low.

In the case, however, of hot water boilers, both riveted and welded, the diameter is limited to 60 in. maximum, the same limit being allowed for both kinds of joints. The Boiler Code Committee evidently considered this diameter safe for welded boilers or they would not have put it in the code. We therefore see no reason why an unfired pressure vessel, which is presumptively less dangerous than a fired one, should not have at least the same maximum allowable diameter.

Pressure and Thickness of Plate

The Unfired Pressure Vessel Code restricts the working pressure to a maximum of 100 pounds per square inch. This seems to be an arbitrary figure, not based on any engineering data or tests. The results of the tests

in Bulletin No. 5 show that it is perfectly safe to design tanks for 250 pounds working pressure, as those that were designed for this pressure with double vee welds failed at from 1200 to 1800 pounds, the average being about 1400 pounds.

The committee believes that pressure is not the correct engineering basis for design, but that fiber stress should be used instead. The recommendations made above as to fiber stress and diameter limit the pressure automatically when the maximum allowable thickness of plate in the code is also considered. Using this thickness ⅝ in., diameter 60 in., fiber stress of 8000 pounds, the maximum allowable working pressure will be 160 pounds, which is for the largest tank suggested, but there is no greater fiber stress, and therefore there can be no more danger, in a tank 30 in. in diameter made of the same plate thickness and carrying 320 pounds. It might also be pointed out that the heating boiler code allows 160 pounds pressure, and it is fair to assume that if this be safe in a fired pressure vessel, more should be allowed for an unfired pressure vessel.

The committee therefore recommends that the maximum allowable pressure be 250 pounds per square inch.

Because of the above recommendations in regard to fiber stress, diameter and pressure, the committee further recommends that any reference to allowable thickness for welding be omitted.

Length of Shell

The Unfired Pressure Vessel Code restricts the length of a welded shell to three times its diameter, if a longitudinal weld be used. Your committee knows of no good engineering reason for this, as far as internal pressure is concerned, although for external pressure there is a limiting ratio of length to diameter. For shells over 24 in. in diameter any length weld can be made. We would also point out that there is no limit in the ratio of length to diameter for any other method of joint, and there is no engineering reason for making a difference in this respect between the different forms of joints.

The committee therefore recommends that the length of any course be limited to three times its diameter for tanks less than 24 in. in diameter. Above this diameter, the committee recommends that there be no limit to the length of shell to be welded.

Contents

The Unfired Pressure Vessel Code restricts the contents of tanks with longitudinal welded seams to air. The committee sees no good engineering reason for this, and would point out that the Heating Boiler Code allows hot water in a fired pressure vessel at 250 deg. F. The committee believes that the contents of the tank has nothing to do with its strength, and that a tank properly welded is just as safe for one content as another. Good engineering requires that in the case of dangerous contents greater precautions be taken in the way of safety devices, prevention of overpressure and of avoiding injury to person and property, but there is no reason why a tank for containing ammonia at a given pressure should be any stronger than should a tank for containing air, for example. The committee therefore proposes that there be no reference to contents in the code.

Temperature and Pressure

The committee does believe, however, that the temperature to which the tank is subjected introduces strains which should be taken care of by providing certain limits for pressure when combined with high temperature. It is believed that a temperature of 250 deg. F. cannot under any circumstances introduce serious stresses into a tank, no matter what the content.

The Heating Boiler Code allows a maximum temperature for hot water heating boilers of 250 deg. F. The committee sees no good engineering reason for not allowing the same maximum temperature for unfired pressure vessels containing hot water. The committee further believes that there is no good engineering reason for prohibiting the use of steam in unfired pressure vessels. Such vessels are used in the chemical industry and for cooking foods and for other similar purposes. The code allows the use of such vessels when they are enameled, but prohibits their use when not enameled, for which there is no good engineering reason. Enameled vessels are frequently designed for 125 pounds working pressure of steam. The fiber stress used by the manufacturers is that provided in the code in section U98. This fiber stress is low, 5000 pounds per square inch of plate

section, but we are advised by those thoroughly familiar with the process of manufacture and with conditions under which these tanks are used, that the fiber stress is kept low only to prevent the steel from stretching enough to crack the enamel. In a tank that is not enameled there is no need of taking this precaution.

The committee therefore feels that there is good precedent for allowing welded pressure vessels with longitudinal seams to be used under a steam pressure of 120 pounds per square inch, and that it would be perfectly safe to allow a maximum temperature equal to that of saturated steam at this pressure, or 353 deg. F.

The committee therefore recommends:

1. That any tank whose temperature does not exceed 250 deg. F. shall be allowed 250 pounds per square inch maximum working pressure.
2. That tanks containing steam be allowed a maximum working pressure of 125 pounds per square inch and a maximum temperature of 353 deg. F.

The committee further recommends that the above rules apply only to welding by hand.

TENTATIVE PROGRAM OF INVESTIGATIONS—PRESSURE VESSELS

1. *Lap Welded Seams.*—Three tanks, each to be supplied by three manufacturers, of the size and working pressure similar to that used in previous investigations at Washington. Tanks to be tested to destruction by hydrostatic hammer test similar to that previously employed.

2. *Single Vee Tanks Automatically Welded.*—Three tanks, each to be supplied by three manufacturers using automatic welding machines. Size and pressure of tanks similar to those employed in previous tests. Tests to be carried to destruction.

3. *Single Vee Tanks Hand Welded on One Side.*—Three tanks, each to be supplied by several manufacturers. Size and pressure of tanks similar to those employed in previous tests. Tests to be carried to destruction. There is a strong belief by many experts that single vee tanks can be consistently made as strong as any other types of joints.

4. *Single Vee Tanks Hand Welded with Slight "Wash Weld" on the Inside.*—Three tanks to be supplied by several manufacturers of same size as those employed in previous tests. Tests to be carried to destruction.

5. *Riveted Welds.*—Three tanks, each by one or more manufacturer using so-called riveted welds. Size of tanks and methods to be similar to that above.

6. *Electric Compression Induction Welding.*—Three tanks, each by one or more manufacturers using the above processes. Size of tanks and pressures similar to above.

7. *Riveted Tanks.*—About six riveted tanks to be tested in same manner as welded tanks and to be supplied by competent manufacturers of riveted tanks and to be secured preferably by a sub-committee on riveting of the A. S. M. E.

8. *Tests on a Few Large Tanks.*—Three extra size tanks to be built and tested per specifications of the committee.

9. *Tanks Made of Heavy Material.*—Tests to destruction on a few tanks made from 2-in. stock, using both single vee and double vee joints in longitudinal seam.

10. *Fatigue Tests on Wide Specimens.*—A number of samples are to be made up to be tested in a machine built during the war and now located at the Bureau of Standards. These samples to include riveted joints, double vee joints, single vee joints hand welded, single vee joints automatically welded, lap welded joints, single and double rivet welded seam joints, combined rivet welded and seam welded lap joints.

11. *High Temperature Testing.*—Fatigue and other physical tests will be made on welded specimens at high temperatures and also with variation in temperatures.

EMPLOYMENT SERVICE

Attention has been called upon several occasions to the Employment Service Bulletin which the Society maintains. Each month there is published regularly a list of vacancies which have been brought to our attention and also a list of men available who desire to secure employment.

Aside from the publication of these records the Society maintains in its office a complete record of experience of those desiring to secure positions and also openings that are available. There is no charge for this service to members. If you are out of a job or desire to make a change, notify the Secretary stating your experience in detail. If members desire to make application for some opening listed in

the Journal this may be done by writing to the Secretary and referring to the number in question. A number of members have already been placed through this employment service bulletin.

WELDED PRODUCTS

In order to make the welding exposition during the fall meeting of the Society in Boston an outstanding success manufacturers who make welded products are urged to exhibit these at the convention. No charge will be made for exhibition space for these products, the only stipulation being that the company should have at least one member affiliated in the American Welding Society. Interested manufacturers are urged to get in touch immediately with Mr. T. A. Wry, Chairman of the Boston Section, General Electric Co., River Works, West Lynn, Mass.

SECTION ACTIVITIES

Chicago:

The first meeting of the Chicago section was held on Sept. 11 in the room of the Western Society of Engineers. About thirty people were in attendance. Mr. J. J. Crowe of the Air Reduction Sales Co. presented a paper on "Economies Through the Use of High Purity Oxygen and Cutting." This paper aroused considerable discussion. A tentative progrom of the Chicago section for the year is given herewith.

Sept. 11.—"Economies Through the Use of High Purity Oxygen in Cutting," by Mr. John J. Crowe of the Air Reduction Sales Company.

Oct. 2.—"Some of the Effects of Oxy-Acetylene Cutting on Steel," by Mr. S. W. Miller of the Union Carbide and Carbon Research Laboratories, Inc., Long Island City, N. Y.

Nov. 6.—"Adaptability of Arc Welding to Structural Steel Fabrication," by Mr. A. G. Bissell of the Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Dec. 4.—"Procedure Control for Welding Cast Iron Heater Sections," by the Publicity Department of the Linde Air Products Company.

Jan. 8.—"Cutting Railroad Cars with the Electric Arc," by Mr. A. M. Candy, General Engineering Department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. This address will include a very complete set of lantern slides based upon the activities of the Pennsylvania Railroad in cutting up cars with the electric arc.

Feb. 5.—"Metallurgy of Welds," by Mr. George A. Ellinger, Page Steel & Wire Company, Monessen, Pa.

March 5.—"Welding Cast Iron Cylinders with Electric Welding," by Mr. George D. Rohder, Superintendent of Welding, Aurora Shops, Chicago, Burlington & Quincy Railroad Co., Aurora, Ill.

April 2.—Paper by Mr. C. A. McCune of The American Chain Company. (Subject to be announced later.)

May 7.—Visit to South Works of the Illinois Steel Co. A paper will be presented entitled "Procedure Control for Welding Pressure Vessels," by the Publicity Department of the Linde Air Products Company.

Meetings will be held in the evening of the dates mentioned in the rooms of the Western Society of Engineers, 1735 Monadnock Building, 330 South Dearborn Street, Chicago, Ill.

Philadelphia:

The first meeting of the Philadelphia section will be held on Sept. 21 in the Engineers Club. Mr. A. G. Bissell of the Westinghouse Electric & Mfg. Co. will present a paper on the "Fabrication of Structural Steel." A program of the Philadelphia section for the coming year is given below: Oct. 19, 1925, Mr. Douden, Sun Oil Co., Marcus Hook, on "Dependability of Welds." Nov. 16, 1925, J. C. Lincoln, Lincoln Electric Co., subject to be announced later. Dec. 21, 1925, Philadelphia Section night, "Welding Par Excellence." Jan. 18, 1926, E. E. Thum, Union Carbide Co., New York, subject to be announced later. Feb. 15, 1926, W. A. Gibb, Gibb Instrument Co., "Seam or Roller Welding." March 15, 1926, J. Belanger, General Electric Co., "Automatic Welding and Its Benefits to the Welding Art." April 19, 1926, Prof. A. S. Kinsey, Stevens Institute of Technology, "Training of Operators and Inspection of Welds."

New York:

The first meeting of the New York section will be held on Oct. 5. Plans are being made to secure a large attendance at this opening session. Mr.

S. W. Miller will present a paper on "Testing the Completed Weld." An opportunity will be provided for the discussion of this paper by the proponents of the several welding processes. Smokes and entertainment will also be provided. The following topics for future meetings have been tentatively agreed upon: Nov. 13, 1925, "Shop and Employment Tests for Qualified Welders," by G. O. Carter. "Determining the Qualifications of the Welder," H. P. Egan. Dec. 16, 1925, "Safety." Author to present this from an insurance viewpoint. February meeting of the Society at the Harrison Plant of the Edison Lamp Works, Harrison, N. J. January joint meeting of the A. S. M. E., local section and New York Section, American Welding Society, on "Pressure Vessels." Dates and subjects of the remaining meetings to be announced later.

Los Angeles:

A meeting of the section was held on June 25, at which plans for increasing the activities of the section were discussed in detail. A three reel moving picture was shown giving the methods of reclaiming the material used by the Southern Pacific Railroad Co. A second reorganization meeting was held on July 21. Considerable progress was reported in the reorganization of the Section. A two reel moving picture showing the manufacture of spark plugs was shown, after which Professor Daugherty of the California Institute of Technology talked on unfired pressure vessels and the problems confronting the welding engineer.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the number Indicated in Each Case and Mailed to Society Headquarters.*

Services Available

A-38. Welder desires position. Acetylene welder of 10 years' experience desires to make change. Capable of taking charge of welding operations. Reference given as to ability and character. Have business experience and can make shop trade expand.

If You Need a Position
Write to the Secretary of the Society

An Outline of Instruction in Oxy-Acetylene Welding*

LIONEL JOHNSON†

In addition to welding we teach automotive mechanics, battery building, machine shop work and tire repairing. Our welding instruction is in the oxy-acetylene process. We do not teach electric welding.

Our main welding course requires from three to four weeks of actual practice in welding work of the different kinds. The student is privileged to stay longer and a diploma is not granted until he shows the required proficiency. This regular course consists of: First, instruction in the use of welding equipment, safety precautions, the nature and use of the gases employed. It is made clear to the student that welding must not be attempted by an untrained man as it requires great skill in the use of the equipment and gases, the heating of the metals and the making of welds. Second, is the actual training in welding. In this one subject is taken up at a time and introduced by an explanatory lecture, after which the student practices under the direction of the instructor. The divisions of this practical training are: Welding Sheet Steel, Brazing, Cast Iron, Aluminum Puddle Welding, Flux Welding, Cutting.

A shorter course in Sheet Metal Welding only, requiring 70 hours' practice, is also offered.

The equipment required for our welding course includes individual outfits for each student, benches, vices, power grind stand, preheating furnace, service plates, clamps, V-blocks, etc. It is important that there be enough outfits for each student to have one, as a student does not learn by watching another work, but by doing the work himself.

The preliminary instruction given the student emphasizes the care that must be taken to see that all hose connections and regulator connections are tight, that the regulators are properly adjusted before opening tanks to insure against damaging regulators. He is then instructed as to the proper method of adjusting regulators so as to maintain a neutral flame at all times, also the effect of an oxidizing flame and a carbonizing flame.

It is desirable to begin the actual welding practice with as simple a process as possible. For this reason steel is first given the beginner, rather than iron as might be expected. There are two good reasons for this. One is that the effect of the oxidizing flame and the carbonizing flame is most easily distinguished on steel. The other is that no flux is required, and a simple weld can be made on steel without the use of filler rod. This enables the student to

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*Presented at March Meeting, Detroit Section, A. W. S.

†Chief Inspectir, Welding Department, Michigan State Automobile School, Detroit.

work with one hand, getting the swing of the torch and learning to run the metal evenly and smoothly. It seems to be unhandy for a man unfamiliar with welding equipment to learn the manipulation of the torch with a rotary motion and the feeding of the filler rod at the same time.

When the student has succeeded in making a smooth, even weld, he is put on brazing of malleable iron. Brazing is another comparatively easy operation. The importance of applying the brass filler without burning is emphasized and the importance of using the proper flux.

The next lesson is on Cast Iron. By this time the student has become familiar with the handling of equipment and torch, and can be given the deeper study which cast iron welding requires. After welding a few pieces together the student notices the expansion and contraction of this metal, in some cases causing it to crack. We then go into detail on this subject, giving a full explanation of expansion and contraction. This metal, cast iron, is second only to aluminum in expansion and contraction, therefore this instruction is an excellent preliminary study to welding of aluminum.

We are fortunate in having an almost unlimited supply of aluminum castings, due to the courtesy of the Bohn Foundry, which supplies us broken parts and exchanges them for others after they have been used for practice welding. This enables us to give the student extensive practice in the welding of this metal. We first teach him the principle of sagging the metal at the point to be welded in puddle welding. The nature of this metal under the flame is to drop very rapidly after it has been brought to a certain temperature, making it essential that the welder be able to note at a glance when metal is at this point. In some cases a very expensive part or casting has been totally destroyed by being thrown out of line or warped by an inexperienced operator. Also the melting point at which the metal can be properly paddled is taught. He is also instructed as to the proper temperature of preheating and reheating before and after the welding process, as care must be exercised while handling a hot casting.

Flux welding of aluminum is the next lesson. The proper radiation of heat through the parts to be welded is made thoroughly clear, as it is, of course, the most important factor in making of a flux weld. Flux welding, we contend, is particularly adapted to metals up to and including ⅜ in. thick.

The student is also taught the way to repair scored cylinders and the other uses to which cast iron soldering can be applied, also aluminum soldering and the many uses it can be put to.

We intend to add to our course soon instruction in cast iron and steel *pipe welding* as this is becoming an important process in the industries.

Cutting is the last lesson given, because by this time the student has become proficient in using the torch and equipment and more

readily understands the importance of exercising care in making different cuts. The different pressures are explained and the proper manipulation of the torch in starting a cut, whether it be across or through the center of the metal. Students are taught to realize the importance of the use of the torch for cutting, and the many ways in which it is now employed.

Lectures are given during the course on the constituents of various metals and parts requiring pre-heating and those that do not.

Our intention always is to make the training absolutely thorough. We realize that too short a course would be extremely dangerous, as it would lead a student to think that he knew how to weld when he did not, and might result in him injuring himself and damaging jobs that he worked on.

To the man who is a welder of several years' experience, the thought comes that it is not possible to teach this trade properly in three to four weeks. Before I was connected with the Michigan State Automobile School I had the same impression. But after knowing the intensive methods which can be brought to use in education, it is plainly seen that a student who follows the instruction closely will get in a few weeks all the fine points that the average welder gleans in as many years under the method of learning by experience.

As far as we can, we suit our course to the time that the student can give. If his finances will only permit his staying three to four weeks, we give him close attention and constant practice during that time. Those that are able often stay one or two weeks longer, which is their privilege. Some go to work days and continue to attend evening classes for advanced practice and review.

We receive considerable commercial work—that is, repair jobs for outside customers. These advanced students are given the practice on these jobs, under the personal supervision of the instructor.

We find the average student is timid when he goes on his first job and sometimes fails at the start for this reason. Invariably, however, when given an opportunity, they make good and prove much better men for their employers than the regular run of welders.

The hours of our classes are 8.30 to 11.45 and 1 to 4.30 daily, except Saturday afternoons. Evening classes are also run for men who cannot stop work to learn this trade in day classes. The evening class hours are 7 to 9.30, Mondays, Wednesdays and Fridays. *Classes are open to visitors at all times.* Goggles are provided for watching the work.

The school conducts a free employment service which is intended as a service both to the student and to employers. We can usually supply a welder to any employer who calls us. We prefer to be given a little notice, if possible, in order to select the type of man suitable to the job.

Growth of the Welding Industry

J. W. MEADOWCROFT*

If we go back to pre-war days we find that the welding industry was more or less at a standstill. In many cases acetylene gas welding equipment was used when arc welding equipment should have been used and vice versa. This naturally caused many failures in the welding art and discouraged many of our foremost manufacturers. The war came upon us very quickly and the welding industry was called upon to prove its real value, and all methods of welding were used to advantage in producing welded products practically overnight.

Competition in welding was not given a thought, as the demand was so great for all types, due to their tremendous value, that the manufacturers of welding equipment soon forgot the idea of using only one method of welding and concentrated on using them all, with only one thought in mind—use the best method both from a standpoint of safety and the assurance of winning the World War. There were probably six or more plants making the same product for use in the war, and in order to devise the best plan for designing and welding the product, meetings were held in various sections of the United States and representatives of the companies manufacturing the same commodity would attend these meetings. After a short discussion a satisfactory decision was always made whereby the method of welding which coincided with the construction of the commodity was used.

In one particular case, where a product was being manufactured for our Government, three different methods of construction and assembly were used and three different methods of welding were used, namely, acetylene, electric arc and electric butt welding respectively. The product, regardless of the method of welding used, was a satisfactory welded product and gave satisfactory results to our Government.

This was just one example of many thousands in the welding of commodities used by our Government during the war, and it was a real object lesson to the manufacturers of welding equipment. It proved to be the actual turning point in the use of the various methods of welding and practically placed the welding industry in its own, and today the many industries throughout the country are using all methods of welding on a large scale. The manufacturers of welding equipment have engineers working constantly with the various manufacturers throughout the country to get the proper methods of welding necessary in the manufacture of their products, regardless of the fact that it may not have any bearing whatever on the sale of equipment in which the engineer is so vitally interested in and represents, yet it is this unselfish spirit of instruction

*Supt., E. G. Budd Mfg. Company.

and salesmanship that has advanced our welding industry to a point where there is a tremendous field for all methods of welding.

The design of the various products plays a prominent part in the method of welding to be applied and our engineers are so designing and constructing their products that the most economical as well as productive method can be used. Many concerns today have welding research men who are constantly finding additional use for the welding art, and it is only a question of time when practically everything we come into contact with in our daily routine will be a completely or partly welded product. Our homes will have steel parts which will be welded, and the many and varied accessories used in connection with our homes which are not already welded will be welded. Automobiles, trolley cars, trains and in fact almost every running vehicle will be welded. Manufacturers in all parts of the world are steadily realizing the importance of welded products both from an economical as well as a productive standpoint, and their engineers are constantly changing the design of their products so as to produce a completely welded product.

Most of the metals have been welded in the past ten years and the question of metal is more or less past history. Let us, for example, go back a few years and we will find that considerable difficulty was encountered in the welding of aluminum, and yet some of the manufacturers of equipment and numerous small shops throughout the country welded aluminum castings successfully, yet could not manufacture a sheet aluminum product and weld it commercially. Today we are welding sheet aluminum products in this country at a much greater speed than we weld any other metals and the teaching of aluminum welders has been less troublesome, than that of any other metal.

This is only one example of the advancement of the welding art, and yet it has and will play a very prominent part in the future growth of the welding industry. Operators are welding at a much greater speed today because of the specialized methods used in connection with the manufacture of welded products, and in our business world today, where competition is keener than ever before in the world's history, we find this item of speed a very essential one; however, quality is not sacrificed in the least. The old idea of a weld appearing to look good on the surface and then fail is more or less forgotten, and as we continue to develop the welding art and hold it to high standards, we will be placing the welding industry in its proper relation to all other industries. The value of the welding art is recognized the world over and its growth will never cease.

Arc Welding Costs

K. R. HARE†

It is believed that the following table, which shows the pounds of metal deposited per hour with different heat values and different sizes of electrodes will be of interest:

Amperes	Electrode, Inches	Pounds Deposited
125	5/32	1.9
150	5/32	2.4
175	5/32	3.2
175	3/16	3.2
200	3/16	4.25
225	3/16	5.3
225	1/4	5.3
250	1/4	6.3
275	1/4	7.25

By referring to the above table, it will be apparent at once that there is a distinct advantage along the lines of increased production in using the larger sizes of electrodes wherever possible. For instance, taking the 5/32-in. size, with the average current of 150 amp., there is deposited per hour 2.4 lb., while 4¼ lb. are deposited per hour with the 3/16-in. size, using 200 amp., and 6 1/3 lb. with the ¼-in., using 250 amp. This means that, where it is possible to use ¼-in. electrodes, a certain job could be done in practically one-third the time required to do the same job with 5/32-in. electrodes.

It has been stated from time to time that the physical quality of the metal deposited by the larger sizes of electrodes, with the higher current values, is not equal to the quality of the metal deposited with smaller sizes of electrodes. Personally, I do not believe that this assumption is correct. I can find no engineering nor scientific reason why it should be correct; and practical experience proves that the quality of the metal deposited with the larger electrodes is equal to that deposited by the smaller electrodes. The quality of the weld is improved and still greater production speed is obtained by using flux coated electrodes, particularly in sizes over 5/32 in.

In this connection I submit for your consideration the belief that the temperature of the arc remains practically constant regardless of whether a 5/32-in. or ¼-in. electrode is being used; and that the extra heat used with the ¼-in. electrode is necessary only to fuse the metal and is not effective in raising the temperature. This is simply an application to arc welding of the well known theory of constant fusion temperature, similar to that of melting ice, where the temperature remains constant. Various values of heat simply change the rate of fusion, but not the temperature.

In regard to the comparative cost of electrically welded and

† Sales manager, C. H. Hollup Corp.

riveted joints, you are referred to the curves shown in Fig. 1. These curves show cost per foot for double riveted, single riveted and welded joints, the electric welding information being based on butt joints. It is interesting to note that for ¼-in. plate the cost of the welded joint is only about one-fifth that of the riveted joints; for ½-in. plate, about one-third, and for ¾-in. and 1-in. plate about one-half.

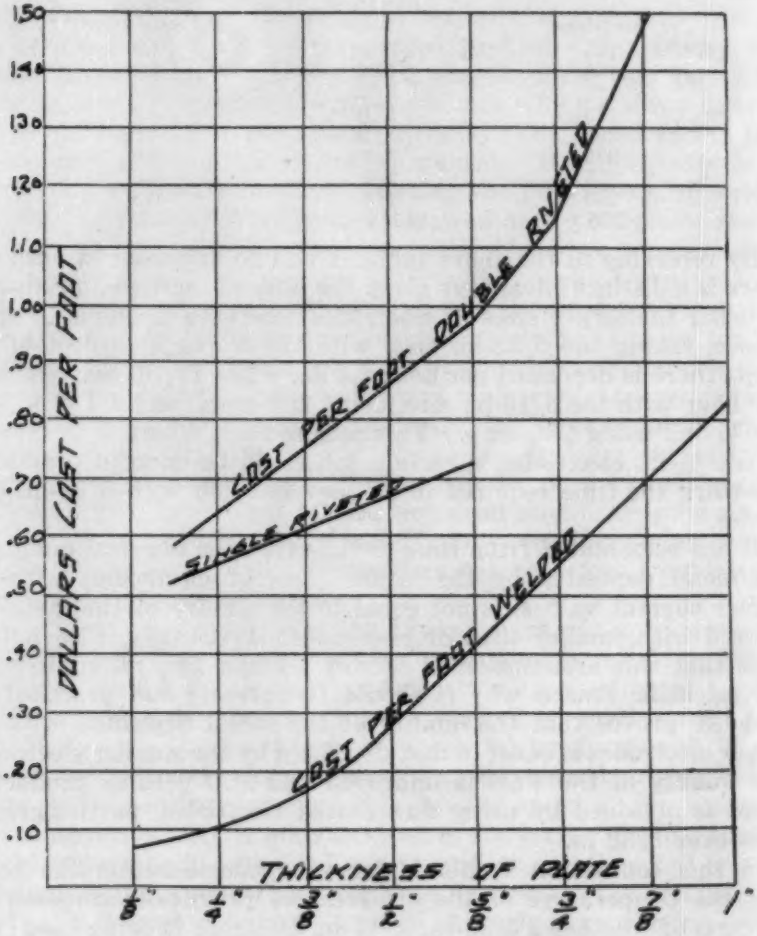

Fig. 1.—Riveting vs. Manual Welding Cost

So much for the cost. However, it will be of interest to make mention of the comparative efficiency of riveted and welded joints by simply stating that the average efficiency of single riveted joints is, in no case, greater than 60 per cent, and averages about 57 per cent; whereas, it would be a poor welder indeed who would average less than 75 per cent. The fact is, the average electrically

welded butt joint is from 90 per cent to 95 per cent, and by proper reinforcing can be made over 100 per cent.

All of the these matters are of more or less importance, but to me the thing of greatest importance in the application of electric arc welding is: Supervision. I think that this subject is worthy of considerable thought by those who are present.

Electric welding, as a process, is so new that it invariably meets a great deal of opposition from those who are in authority, but who are not familiar with what can be done, and what it being done, by electric welding. It is, therefore, necessary, in order to overcome this psychological inertia, for some one to be in charge of electric welding so that the process is extended and used where it will be of the greatest advantage. I would not say that such a supervisor would have to be an expert welder himself; but he should be an expert mechanic, familiar with mill conditions and what can be accomplished by welding: and it should be his job to pick out the work that can be accomplished by welding and foster the process along in his own plant in such a way as to finally convince those in authority regarding its true merits.

I have in mind two large steel plants in the vicinity of Chicago, both owned by the same corporation. One of them is making very good use of electric welding and is saving thousands of dollars which is due to the application of this process in repiar and new construction work, simply because this work is under the direction of a supervisor who is aggressive and has the courage of his convictions. In the other plant, which is perhaps even larger and has greater opportunities for welding, there is only one machine and they are not making full use of it. They probably never will obtain the full benefits which may be derived from the use of this process until some one is placed in charge who will take an active interest in it and initiate the various applications of the process which must be started in the face of prejudice and inertia.

Employment Service Bulletin

If you are in need of a position or have a vacancy in your staff, please get in touch with the Secretary of the Society. This service is free to members.

Advancement in the Gas Cutting of Metals*

By Alfred S. Kinsey†

It seems but a short time ago that the mechanical engineering world was thrilled by the discovery of a new way of cutting metals, seemingly a simple thing to shop practice, but highly important, nevertheless. It was different from the common methods employed for such purposes, which depended on the principle of *mechanical abrasion,* and used saws, drills and other steel tools to do the cutting. By the new method the cutting was done by the principle of *chemical oxidation,* using a high temperature flame for the work. The mechanical tool could wear its way but slowly through hard metal, whereas the new flame accomplished the same penetration by oxidation in a much shorter time.

For some time not very much was expected of this new way of cutting with the gas flame. The mere fact that it would cut through steel quickly and make it of scrap size seemed to be sufficient to warrant the adoption of gas cutting in many shops scattered over the country.

It was well known that under natural atmospheric conditions the law of the oxidation of metals operated comparatively slow, in fact in some cases many years being required for oxygen to work its way completely through a piece of metal like steel. But this was explained by the fact that the activity of the oxygen was retarded by the inert gases of the air and normal air temperatures. Therefore it was not practicable to think of cutting metal by the use of air. Such rapid oxidation required oxygen of a higher purity than that of the 20 per cent purity found in the atmosphere. The first commercial liquid air oxygen was of a purity of about 97 per cent. This as the supporter of the combustion of a rich combustible gas like acetylene produced a flame of remarkable metal cutting capabilities.

Again, it was known that while atmospheric oxygen would attack metals, particularly iron and steel, when they were at the temperature of the air, it was also realized that the speed of oxidation could be greatly increased by first heating the metal to its critical temperature, a bright red. A simple illustration of this principle was to be found in any blacksmith shop where the hot metal, while being hammered on the anvil, could be seen to quickly burn and flake off red hot oxides which turned black by the time they reached the floor. It was apparent that in order to obtain the best cutting action from the use of manufactured oxygen it was necessary to provide a means of first raising the temperature of the cold metal to a red heat before applying the oxygen. The oxygen torch, there-

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*Presented by title at the May Meeting, Boston Section, A. W. S.

fore, was designed so that its preheating flame first would heat red hot a spot on the steel, and then project upon it a stream of oxygen which would quickly burn its way through the entire thickness of the metal.

Owing to the purity of the oxygen the speed of cutting is rapid, but it would be increased were it not for some of the chemical elements lying in between the grains. It takes much longer, for example, to cut cast iron with its 7 per cent of chemical elements than to cut low carbon steel with its chemical contents of about 0.7 per cent. It will therefore be seen that the successful use of the principle of cutting metal by oxidation depends on a special torch with a preheating flame and on the purity of the oxygen.

So, while in the first gas cutting of metals the object was merely that of reducing big pieces of steel to scrap size, and any questions of speed, quality and economy of cutting were hardly considered, it later was found that the cutting torch could accomplish much finer results than had been realized. This resulted in greater care being taken in the handling of the torch. In fact, it soon became common practice to require smooth, accurate cutting, and a record of the amount of gas consumed.

However, so far as efficiency and economy were concerned, it was generally supposed that they would be found in improvements of the design of the cutting torch, and as to speed of oxidation, 97 per cent oxygen was considered to be pure enough to produce satisfactory results.

Then another advancement was made in the gas cutting of metals when machines like the radiagraph and oxygraph were built which would operate the cutting torch by power. These made it possible to increase the cutting speed from 50 per cent to 100 per cent over the best which could be done with the hand torch, 97 per cent oxygen being used for the work. For example, steel plate one-half inch thick could be cut with the hand torch at the rate of about 50 linear feet per hour, and at nearly 100 linear feet per hour with the machine operated torch.

The next step in the progress of the gas cutting of metals was a consideration of the quality of the cutting, the amount of slag adhering to the surfaces, and the general accuracy of the cut. It was at this period that the purity of the oxygen was found to have much to do with the smoothness of the cut, and particularly with the character of the slag produced. The purer the oxygen the more completely the iron base metal of the steel was consumed, and the resulting slag, or ash of the burnt iron, was so free of metal that its tendency to adhere to the surfaces of the cut was reduced to a degree which caused the slag to be easily blown away by the cutting flame. Therefore the purity was advanced from 97 per cent to 98 per cent, and this quality of oxygen became the standard product. The value of this was shown by a marked improvement in and a wider application of the cutting of steel in the best shops.

The latest chapter in the history of the development of the gas cutting of metals is of special interest. From time to time changes had been made in the design of the cutting torch, including arrangement of the size, number and location of the holes in the tips, and this brought about an increased economy of gas consumption.

In the meantime there lay just within reach a possible way of increasing the quality, speed and economy of gas cutting which had apparently been little observed and probably was then unappreciated. This secret was that there still remained the possibility of a substantial progressive gain in the efficiency and economy of the gas cutting of steel as the oxygen was increased in purity up to at least as high as 99.50 per cent. For illustration, in some cutting of ⅜-in. steel plate it required about 10 per cent less oxygen when the purity was 99.00 per cent than when it was 98.50 per cent, and the percentage of oxygen consumption decreased another 10 per cent when the purity reached 99.50 per cent, a total gain in economy of about 20 per cent as the purity was increased from 98.50 per cent to 99.50 per cent. As an increase of efficiency in any branch of shop practice had always proved acceptable, there could be no question about the welcoming of a further improvement in the economy and efficiency of the gas cutting of steel. However, to produce 99.50 per cent oxygen meant important changes in oxygen manufacturing machinery, and this naturally had to be considered in balancing the advantages of the possible gain from the higher purity of the gas.

It has therefore come to pass that 99.50 per cent oxygen is now readily available to any plant in the country, and the results to be expected from its use are about as follows:

1. The cutting efficiency is quite sensitive to small increases in the oxygen purity above 98 per cent.

2. Tests show that there is a saving of from 10 per cent to 20 per cent in oxygen consumption, and an equivalent saving in time when the purity of the oxygen is increased from 99 per cent to 99.5 per cent.

These should be interesting and valuable facts for users of the oxygen cutting torch. A reduction of even 10 per cent in oxygen consumption means a saving of 1 cylinder out of every 10 cylinders of oxygen formerly required to carry on the work. The quality of the cutting is also markedly improved, less slag, less burning below the side surfaces, less time required to do the work. Of course, the advantages of high purity oxygen are specially noticeable in the use of the power cutting machines.

Welding in the Enamel Lined Tank Industry*

By W. B. Miller†

The enamel lined tank industry is dependent on welding for its existence, for a welded joint is the only kind that can be satisfactorily enameled. The industry is unique and today two companies comprise the major part of it. Some of the methods employed in fabricating the tanks preparatory to enameling are therefore peculiar and differ somewhat from the procedure followed in other tank welding shops.

The Pfaudler Company of Rochester, N. Y., was one of the early users of the oxy-acetylene welding process as a regular manufacturing tool, and it will not be amiss to describe briefly the evolution of welding in that plant.

The first product of the company consisted of small cylindrical fermenting tanks which were made by rolling a cylinder from boiler or tank plate, and welding the ends together. The ends of the cylinder were then flanged to a right angle, this flange being punched, and punched dished heads were then bolted on to the rings, completing the unit. Later on, large storage tanks were made by bolting together any number of flanged rings, 4 ft. in width and 10 ft. in diameter.

Forge welding by hand was the first method used to join the ends of the rolled plate. The lapped ends of the plate were heated for a short distance over an open coke fire and this section then hammered by two men using heavy sledges. Four men were required to work on a ring and production was obviously small, but was considerably increased by the adoption of Bradley power hammers, and the use of small electric furnaces to heat the ends of the plate. Often a weld was found defective and it is almost impossible to repair a hammer weld. It might be stated here that the first use of the oxy-acetylene torch at the Pfaudler Company was to repair defective hammer welds.

April, 1907, is the earliest correspondence that can be found relating to the use of gas welding by the Pfaudler Company. In answer to an inquiry, a letter was received from Vollkommer-Reich Company, Pittsburgh, Pa., engineers and contractors, welding installations (autogenous and electric), to the effect that they could weld 25 ft. of ¼-in. plate and about 20 ft. of 5/16-in. plate per hour, in both cases the metal being heated to a cherry red. Their agent, A. Beltzer, welded three sample cylinders at the Fore River Shipbuilding Yards, Quincy, Mass., in May, 1907. The data available show that one cylinder, probably about 3 or 4 ft. long, was welded in one hour, using 26 cu. ft. each of oxygen and acetylene. Oxygen was quoted at about 5c. per cubic foot and acetylene at 1c. As a result of this preliminary work welding equip-

*Presented at Annual Meeting, A. W. S., April, 1925.
†Metallurgist, Union Carbide & Carbon Research Laboratories.

ment was installed. The generator was a "Hero" brand made by Landsberger & Company, Mannheim, Germany, and carried a charge sufficient to run a torch a little over an hour with good luck attending the operation. The torches were very similar to the present day Messer torch and proved quite satisfactory. Only recently have these three torches been discarded. Oxygen was generated by the Lavoisite process, using hypochlorite and a cobalt sulfate catalyzer. This source of oxygen was very unsatisfactory. At the start bottled oxygen was not available in large quantities and an order for fifteen cylinders was the occasion for a large celebration at one of the first plants at Buffalo, N. Y.

About 1915 experiments were conducted at the Pfaudler Company by O. A. Kenyon, out of which came the development of the Constant Current Closed Circuit system of arc welding. One six-panel machine is still doing duty, having been used continuously since its installation, about 1916. Even in those days coated electrodes were used and experimented with. This little bit of history, perhaps not so interesting to many, is given to show in a small way some of the obstacles encountered by the pioneer users of fusion welding.

Fabrication

The fabrication of the tanks consists of the rolling of the cylinder and butt welding of the longitudinal seam. To this cylinder are butt welded standard boiler heads. It will not be necessary to elaborate on the design, etc., for the most important factors have been found to lie in the fitting and welding, which are more or less independent of the design.

In welding up units for enameling all joints are welded on the inside, the weld being ground off flush with the plate and the whole inner surface of the tank sand-blasted for enameling. Glass enameling, which is performed at an average temperature of 1500-1750 deg. F., depending on the type of enamel, is a severe test on the quality of a weld. Gas pockets, voids and blowholes result in blistered enamel over the welds. Deposited metal containing a high gas content results in a porous bond between glass and weld, with the subsequent lifting off of the enamel. When such a condition occurs, the pot must be sent back and rewelded at such areas. This not only entails the cost of rewelding, but also resandblasting and reenameling, which rework is exceedingly costly. Under such circumstances, the logical thing to do is to insure that the welds are right when the units leave the fabricating department.

Observations in the welding department showed that most trouble on the welds developed at places where the fit was poor or where the proper V was not maintained. Poor fittings and improper preparations of the edges to be welded were found to result in lack of penetration, adhesions and fissures. The occurrence of

these defects can be avoided by a good welder even though the fits, etc., are not as good as they might be. In reality the defects above mentioned are due to a lack of knowledge of proper technique which has permitted the use of improper methods. While it is true that many welders have given thought and study to their work and have acquired a method of execution which will give results acceptable from the triple viewpoints of speed of execution, consumption of gas and strength of joint, yet these welders would probably have difficulty in producing satisfactory welds for enameling.

The first step toward bettering the quality of the welds was to install a large boring mill on which boiler heads were tooled off to a plane and properly beveled. Next, a specially made planer with a 20-ft. bed was put into operation to bevel the sides of the large plates before rolling into cylinders. The ends of the plates were beveled on a rotary bevel shear, using a roller guide to insure a straight cut. Welders used to fit and assemble the pots preparatory to welding. A special crew now does all the fitting and tacking and all a welder has to do is weld. On account of the severe heat, especially in the summer months, inside the double headed tanks, it was impossible for a welder to keep welding for any length of time. An exhaust system with a capacity of 2500 cu. ft. per minute was erected with flexible metallic hose outlets to put into the manholes and nozzles of the tanks. This was one of the best investments ever made in the welding department for it made the men more satisfied and comfortable and resulted in increased production.

Having obtained good fits, bevels and working conditions, attention was directed toward a personal inspection of each welder, paying strict attention to his technique, tip size, gas pressures and flame adjustment. In a short time it was found that no two men welded alike. In some cases the welders adjusted their flames to the oxidizing side. This could usually be detected by foam on the molten weld metal and apparently too much heat for the tip size. Some of the men found that better speed could be obtained by sloping the torch head so as to blow the flame ahead of the puddle. This is one of the easiest ways to get adhesions that I know of and is one of those habits a poor welder drifts into. One weld made in this way caused considerable trouble in the enameling department and subsequent examination showed the deposited metal to be extremely dirty and no doubt full of gases, which caused a bubbled condition in the enamel. This sloping of the torch head makes a large, oblong puddle which cannot be protected from atmospheric influence by the envelope flame of the torch.

Experiments in the laboratory showed that by "welding backwards" both quality and speed could be increased, usually with a smaller tip size than had previously been used for the same thick-

ness of material. This method of execution seems to work better on single V welds. Very satisfactory results, however, can be obtained by applying this method to double Vee welds. Since some of the product of the company was for low pressure or none at all, also on account of the increase in quality and speed, it was decided to single Vee weld these tanks and to change all the welders over to the back-hand method. It was no easy task, especially when some of the welders had been welding their way for over ten years. However, the men soon saw the advantage of the method and were highly in favor of it. Since its adoption no trouble has occurred on the welds in the enameling department, and production has been materially increased. The back-hand method produced narrower welds which required much less grinding, which is a costly operation.

As to training new gas welders, no set rules of instruction have been adopted. Any new man first works for some time with the erecting crew until he is familiar with how the fitting and tacking should be done. During this time he has considerable opportunity to observe the welders and get an idea of how they work. His next step is to weld small plates together. The welds are broken and the defects and their causes are carefully explained. When he has shown suitable proficiency, he is allowed to weld in small pots or on rings. He is watched closely and when told to weld this way or that, the reason why is carefully explained, for it was found that a man performed his task more intelligently when he was told the "why."

So far what has been said has concerned gas welding only. Proper fit and preparation of the material for welding results in better welds in arc as well as in gas welding. New men are usually allowed to help in fitting and tacking and are then allowed to practice running beads on a flat plate. In a short time the man has developed a skill sufficient to allow him to work on small jobs where the welds do not carry stresses of any magnitude. No testing of welders is done. A supervisor who knows his job can instinctively tell whether the arc is functioning properly; however, direct observation by a capable man is necessary to tell whether or not the welding is being done properly. An interesting incident came up which shows how important a place proper supervision occupies in successful welding. An arc welder applied for work, insisting that he had had six years' experience welding in one of the largest shops in the United States. Being so insistent on his qualifications he was put to work arc welding a jacket for a pot. The welder was given further opportunity to demonstrate his skill, but never showed much improvement. We were surprised to learn later that this welder was considered an expert at the place of his previous employment. I am quite sure that whoever had direct supervision over the welder knew nothing about welding. The supervision, to my way of thinking, was entirely

to blame, and the sooner officials realize that there is more to welding than just melting of metal, the sooner will welding gain a higher plane and become better recognized among engineers. There seems to be a prevailing idea that there is something mysterious about welding. This is erroneous, for when sanely considered welding is an easy operation when certain fundamental principles are observed. Just so there are certain principles which must be observed in order to fabricate a pressure vessel properly by riveting. Under proper supervision, with plate of good welding quality, and with good welding rod, a welder can be trained in a comparatively short time to do a particular type of work. That this is true has been demonstrated many times.

Thus good results in welding at the plant of the Pfaudler Company have been obtained by proper fitting and preparation of the edges to be welded. Comfortable working conditions aid materially in the production of good welds. Careful supervision has resulted in the adoption of methods which give welds free from lack of penetration, adhesions and fissures.

Training of Operators and the Method of Testing Welds in the Resistance Process*

H. A. WOOFTER†

In the Resistance Process the training of operators is a very minor and almost negligible matter. The welder itself when once properly set up for any particular job, takes care of nearly all of the different factors entering into a weld. This is especially true in automatic types of machines, whether of the butt or spot variety. In these automatic machines, the only responsibility of the operator is to put the work into place and either step on a treadle or push a lever. The machine does the rest. In hand-operated machines where the operator presses up the weld by means of a lever or pressure jack, it is only a matter of exerting enough pressure to make the metal yield properly, just like pushing the handle of a pump. It is necessary, of course, in hand-operated machines that either the operator himself or the foreman of the welding department should set the automatic cutout so that the current will be discontinued at the proper time. When this cutout is once set, it need not be changed as long as the operator is working on that particular size of stock.

During the war over 3,000,000 boosters for high pressure shells were welded by the resistance process, mostly by girl operators, who had never made a weld before coming on to that particular job. After an hour or so of instruction and trial the new girl

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*Presented at Annual Meeting, A. W. S., April, 1925.

†Electrical Engineer, Thomson Electric Welding Co.

could do just as good work as a trained operator, since the machine itself is the main factor and remains fixed. There was not a single case of leakage or failure reported from the Government in this lot of more than 3,000,000 welds.

Now as regards the testing of welds, this is taken care of in different ways in different industries. On the booster job for the Government referred to above, about every so often a weld would be taken and tested to destruction. In the automobile rim and wheel industry the rims are welded up from flat stock and are then rolled, crimped and stretched to size, which in itself is a test of the weld, no further tests being driven. In various other processes they take a few samples of the stock to be welded, try out a few welds until the proper setup is secured, break the welds if possible until the strongest weld is obtained, then tighten up the machine for that particular setting and no further test is necessary.

In the locomotive repair industry the method of testing welds varies. Some locomotive shops test each tube by applying live steam at about 250 lb. pressure per square inch. Others use hydraulic pressure at about 300 lb. per square inch. Still others use compressed air and apply soap and water with a brush on the external side of the weld to see if any bubbles appear. Still others do not test the welds at all, having found that after welding and testing several million flues the welds are so uniformly strong that the money expended for testing is practically wasted.

In seam welding cans, containers, tanks, etc., the welds are usually tested, if at all, by filling the article with compressed air and submerging it in a tank of water heavily charged with soap. If any leaks are present, they are instantly shown by a train of bubbles, are marked and repaired. In welding of copper wire for drawing to smaller sizes, the test of the weld is in the drawing process itself. Many concerns who have been welding their product for years make no test whatever of the welds since they have found in practically all cases that the weld is stronger than the original metal itself. In the manufacture of metal furniture, such as filing cabinets, clothing cabinets, metal book cases, etc., the test is always made in the testing room by an experienced operator on samples of the particular stock to be used until the proper setup is determined, after which the machine is set and an operator put on the job. No further tests are necessary.

The Effect of Heat on Steel, Especially During Fusion Welding and Cutting*

S. W. MILLER†

Let us first consider what steel is, though for our purposes we should not be too technical, but should talk of steel as a material we handle daily. We are not so much interested in a definition that will cover every possible point, or that will enable us to classify steel with scientific exactness, but we are interested in understanding what we are using, so that we can do our work intelligently and therefore properly.

For our purposes, ordinary steel consists of the element iron, which has added to it small amounts of carbon, manganese, silicon, phosphorus and sulphur, all of which are also chemical elements. We know that steel is ductile, while cast iron is not, though it also contains all of the elements mentioned. This ductility makes it easy to distinguish steel from cast iron.

As the usual steel handled by welding is forged or rolled, I think it will be best to consider only these varieties, for the sake of simplicity, so that we will talk mostly about plate, sheet, and bar steel, and forgings made from what is called plain carbon steel. The so-called alloy steels are so numerous and of such special composition that each one should be considered by itself; also as they are seldom met with in welding, the average welder should get expert advice before doing any important work with them.

The steels we are considering contain varying amounts of the elements referred to, but even the greatest amounts are very small compard with the amount of iron.

The range of these elements in different steels is well illustrated by the following:

	Forging Steel Per Cent	Gas Welding Wire Per Cent	Electric Welding Wire Per Cent	Plate and Bar Per Cent	Tool Steel Per Cent
Carbon	.40	.06	.15	.20	1.10
Manganese	.50	.15	.50	.40	.70
Phosphorus	.05	.03	.05	.05	.025
Sulphur	.05	.03	.03	.05	.025
Silicon	.15	.03	.03	.05	.03

Of course each class has variations from these figures, but they show in a general way what has been found suitable in practice for the purposes for which they are used.

As it is not possible to make steel to such exact figures as given, it is necessary to allow in specifications a range for each element.

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*Presented before Western New York Section, A. W. S., June, 1925.

†Consulting Engineer, Union-Carbide & Carbon Research Laboratories.

For example, the standard specification for firebox plate is:

Carbon	.15% to .25%
Manganese	.40 to .60
Phosphorus	.05 maximum
Sulphur	.05 maximum

So it must be expected that in any steel material there will be variations in the chemical analysis of different shipments.

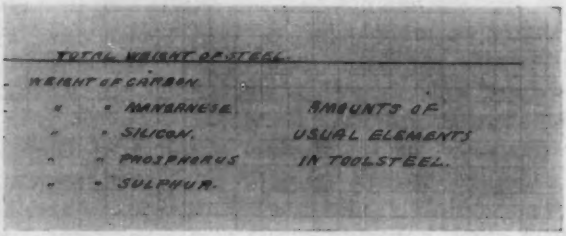


Fig. 1. Diagram showing relative amounts of the various elements in tool steel. The lengths of the lines are proportional to the percentages of the elements

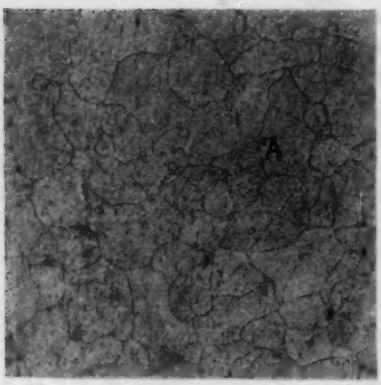


Fig. 2

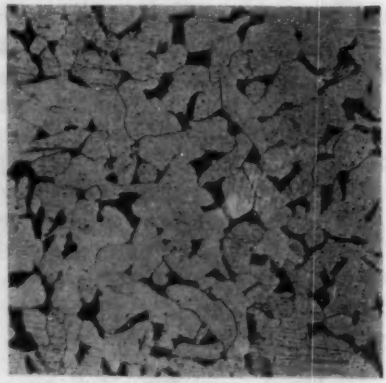


Fig. 3

Fig. 2. Steel wire of about .05% carbon. The minute cementite grains may be seen in several places on the photograph, namely at A. 100X

Fig. 3. Steel of .23% carbon. The black areas are pearlite, the white ferrite. The dark lines are the grain boundaries. 100X

So as to visualize what these amounts of the elements mean, Figure 1 has been prepared. It is for tool steel and shows clearly the really very small amounts present, while in other steels there are still less carbon and manganese. It seems surprising that such small amounts should have so great influence on the properties of steel, but so it is, and of them, carbon is by far the most important.

Pure iron has a tensile strength of about 45,000 pounds per square inch, while the addition of one-half of one per cent of carbon

to it increases the tensile strength to about 80,000 pounds per square inch.

It should be said that while carbon, manganese and silicon are useful additions, sulphur and phosphorus have distinctly bad effects, and are always kept out as much as possible.

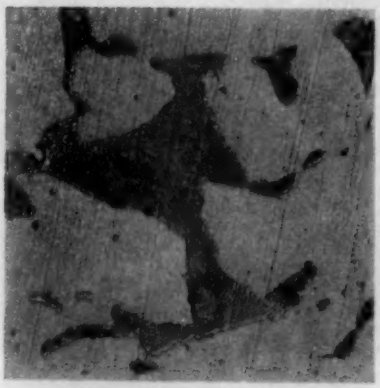


Fig. 4

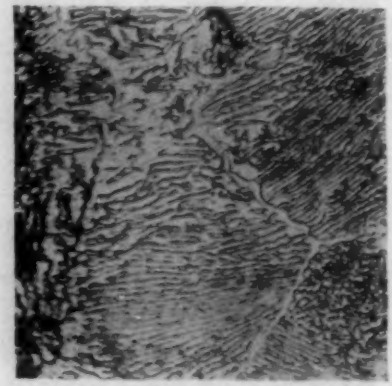


Fig. 5

Fig. 4. Same steel as in Figure 3, but at high magnification. This shows the laminated character of the pearlite. 430X

Fig. 5. 1% carbon or tool steel greatly magnified. The laminated structure is pearlite. 1200X

These elements are all soluble in melted steel, just as sugar is soluble in water. In cold steel, when no more than the usual amounts are present, they are still in solution, except the carbon, which crystallizes out, much as sugar does from hot syrup when it cools. The difference is that the sugar comes out as sugar, while the carbon takes the form of iron carbide, a true chemical compound, which is visible under the microscope. It is a hard, brittle material, and when there is only a small amount of it, looks like Figure 2, which is from a section of welding wire containing about .05 per cent of carbon. With more present, it forms a laminated structure with some of the iron, as in Figures 3 and 4, which is called pearlite because of its pearly luster. This steel contains about .23 per cent carbon.

As the amount of carbon increases, so does the amount of pearlite, until at about .9 per cent carbon the whole structure is laminated, being all pearlite, as in Figure 5.

You have seen in Figure 2 the network of dark lines. These are the boundaries of the individual grains, which are true crystals, though their shape is deceptive. Figure 6 shows roughly how these grains are built up from individual atoms, which may be likened to bricks in a wall, except that there is nothing between these atoms, they being joined and held together by atomic forces, much as the earth and the other planets are held to the sun by the force we call gravitation. While there is

nothing between these atoms themslves, there is material between the grains. You can easily see that during the formation of the grain any foreign matter will be forced out of the way when the atoms unite one to another, and that eventually there must be a line of this foreign matter at the meeting surfaces of the grains. Figure 8 shows just what happens in a steel casting, although, of course, this is a very bad piece of steel. It also requires but little thought to see that this dirt cannot be moved from its location in

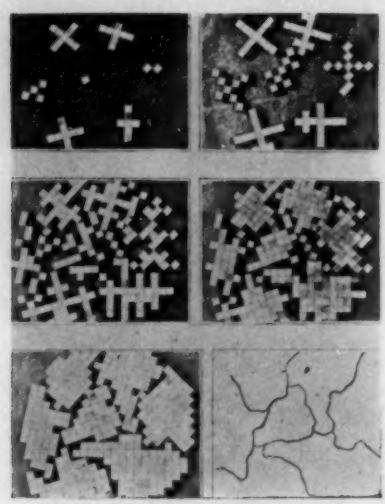


Fig. 6

Fig. 7

Fig. 6. This shows five stages in the growth of the grains of steel from the molten condition and the final result with only the outlines of the grains showing. This scheme was devised by Rosenhain to illustrate the different orientation of adjoining grains

Fig. 7. Perfect crystals of iron which formed in a cavity of a casting during solidification. This photograph was taken from Howe. ¼ Nat. size

the casting by heat treatment, although it is possible inside of these dirty grain boundaries to make changes in the structure of the steel. This is the real reason why comparatively little improvement can be made in the strength and other physical properties of some steel castings by heat treatment.

A very interesting experiment can be made by making a concentrated solution of almost any chemical salt, ordinary salt being very good, and allowing it to evaporate at ordinary room temperature. If you do this, you will notice that as the solution becomes more concentrated minute crystals will begin to form in many different places on the bottom of the dish. There is no regularity as to their location, and the reason for this random beginning of crystallzation is not exactly known. It is enough for our purpose to know that the same thing takes place in steel as it cools down,

although, of course, the crystallization is very much more rapid than in the case of the salt solution.

As the salt crystals get a little larger they should be turned over so that they can be built up regularly, and depending on what the

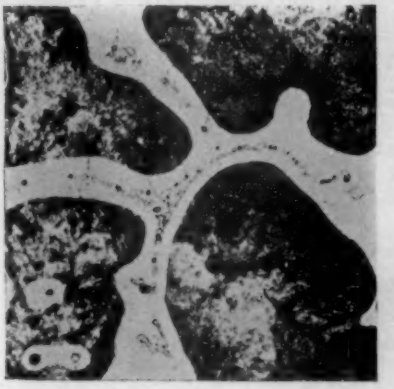


Fig. 8

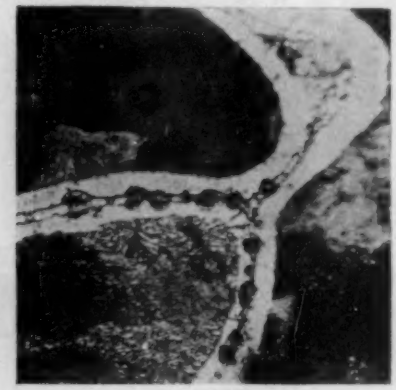


Fig. 9

Fig. 8. Cast steel which contained a large number of inclusions. They have been forced to the grain boundaries during cooling and so outline each grain. 100X

Fig. 9. Another case of rejection of material to the grain boundaries. This is a .70% carbon steel cooled rather rapidly, so that besides the dirt considerable iron carbide was also retained at the grain boundaries. This made the piece brittle and weak. 430X

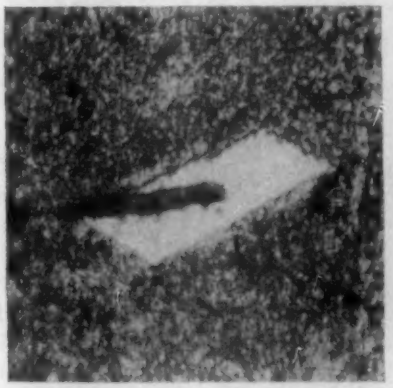


Fig. 10

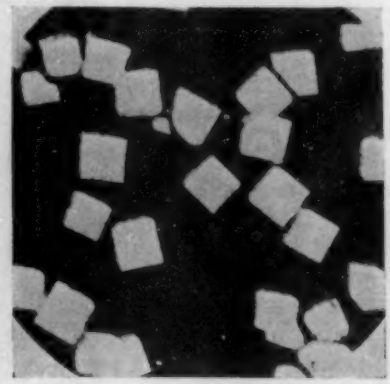


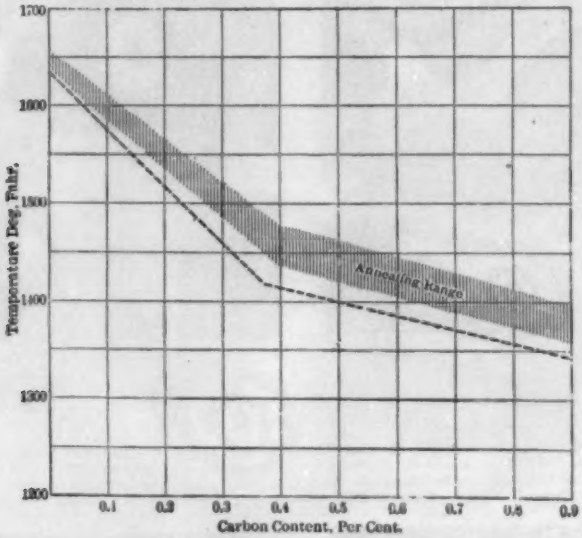
Fig. 11

Fig. 10. A view of regular shaped ferrite crystal which was found in a welded piece. 1200X

Fig. 11. A group of iron crystals obtained by Stead. In many cases they are perfect cubes and so show that iron crystalizes in the cubic system. 250X

salt is, the crystal will gradually grow in the form of a cube or other regular geometric solid, some of the forms being exceedingly beautiful. In this way, regular crystals can be built up of any size desired. This shows that it is quite consistent to believe that the internal structure of a grain in steel is entirely crystalline, although

the outline of the grain is rounded, as was shown in Figure 2. It is not common in steel to find these regular grains with geometric outlines, but under certain conditions they exist. Figure 10 shows a grain of ferrite, or pure iron, in a piece of steel. Iron crystallizes in cubes, and Figure 11 shows some microscopic grains of pure iron.



Annealing Range for Carbon Steels

Fig. 12. A diagram indicating the temperatures at which various steels are subject to heat treatment. Annealing should be done in temperatures indicated by the shaded area. Taken from Bullens, "Heat Treatment of Iron and Steel"

The foreign matter or impurities at the grain boundaries, of course, are weaker than the steel, so that steel containing this foreign matter or dirt is weak. While it is not possible to move this dirt by heat treatment, it is evident that forging will break it up and displace it, so that the forging will be stronger than the casting from which it is made, but it is also clear that if the steel be heated again to a very high temperature, say just to the melting point, the dirt will again collect at the grain boundaries, with the same weakness as was originally in the casting.

There is one other point that we should understand before we go too far. Steel in the melted condition is not crystalline. It is only when it solidifies that it becomes so, and it has been found that there is a slight difference between the exact form of crystallization for some distance below the freezing point and the form which exists at room temperature. While this may seem in most cases of little practical importance, it is a vital change in the steel, because on the temperature at which this change takes place depends almost entirely the heat treatment of the steel. This temperature varies with the steel, particularly with the carbon content

in plain carbon steel. With alloy steels the alloying elements have a great effect. In the steels we are considering the temperatures at which the change takes place are shown in the diagram in Figure 12, which is the basis of heat treatment of plain carbon steels. If the steel is heated just within the shaded area, and held there long

Fig. 13

Fig. 14

Fig. 13. Full size view of quenched tool steel obtained by heating the right end to the melting point with a torch and quenching the entire piece in water. The sharp line at A represents the limit of the heat effect. Full size

Fig. 14. Specimen of bar steel treated similarly to the tool steel. The heat affected zone is not as contrasted as in the tool steel. Full size

enough, its form of crystallization will be changed to that appropriate to high temperatures, and on cooling below this line the crystallization will change to that appropriate to room temperature. This change is not instantaneous, because all changes require time, but it begins at the proper temperature, and takes place over a few degrees below it in a time depending on the rate of cooling; the faster the cooling, the more rapidly it occurs.

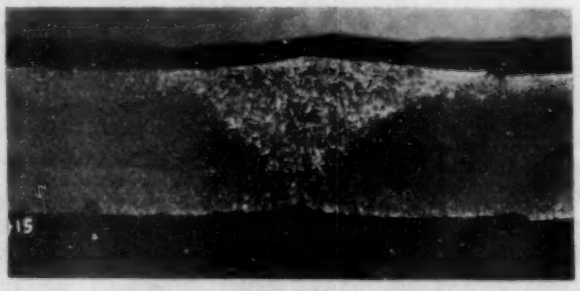


Fig. 15.—Macro etched weld in fire box plate. The weld is easily distinguished by its darker color and the extent of the effect on the base metal is shown by the varying crystal size. X2.

As we have seen, there are certain grain boundaries at high temperatures which are caused by impurities in the steel. Evidently on cooling past the appropriate temperature, these grain boundaries do not change if there is any foreign matter in them, but there is nothing to stop changes inside of these grain boundaries, and the effect of the heat treatment described is to decrease the size of the grains inside the high temperature grain boundaries by breaking up the high temperature grains into smaller ones, thus increasing the strength and ductility of the steel.

Having seen what occurs when steel is heated, let us see what effect the heat from fusion welding has, and it is well to start out with the understanding that the heat from a welding torch or electrode produces no results on a piece of steel that is not produced when heated in a furnace or by any other means. The only difference between the different methods of heating is the intensity. A furnace does not have as intense heat as a welding torch, which in turn is less intense than an electric arc, so that if the end of a piece of steel be heated in the furnace to a certain temperature, there will be time for the heat to be conducted quite a distance from the end. With a welding torch, heating to the same tempera-

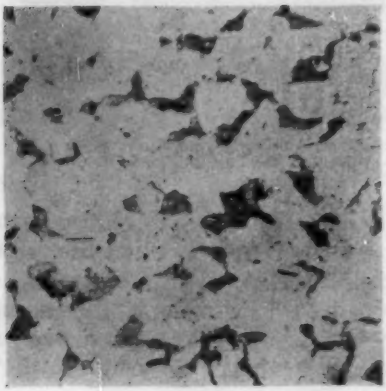


Fig. 16

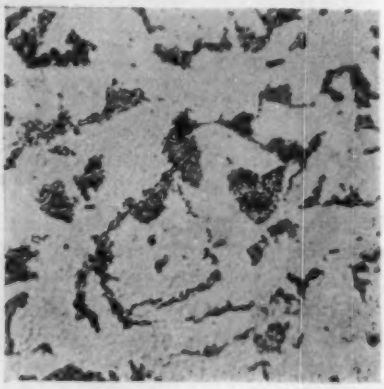


Fig. 17

Fig. 16.—Structure of original material of both weld and heat treated specimens. 430X

Fig. 17. Structure of tensile test pieces Nos. 1, 2 and 3 heated to 1400 deg. F. for 10 minutes and cooled in air. The pearlite has just started to break up. 430X

ture will take place in a shorter time, and with an electrode in a still shorter interval. This means that any changes that take place in the steel cover a long distance in the case of a furnace, a shorter distance in the case of a welding torch, and a still shorter distance in the case of an electric arc.

Figure 13 shows the effect of heating a piece of tool steel quite hot on the end with a welding torch, and quenching it in water, to retain as much as possible the structures all along the piece.

Figure 14 shows a piece of ordinary bar steel subjected to the same treatment. You will notice that the same general effect exists in both cases, although because of the larger amount of carbon in the tool steel, it is more strongly marked in that piece. The specimens themselves possibly show more clearly these changes than do the photographs. You will notice that the tool steel is file hard down to the light zone, while the bar steel is not. This is again due to the amount of carbon in the tool steel.

Of course, during welding, we do not ordinarily quench the piece, but with the kind of steel usually welded, which is similar to the bar steel, even quenching would have little effect on its qualities. The quenching was only done to show as closely as possible what actually occurs in the steel by heating. If the tool steel had not been quenched, the same changes would have taken place, but on account of the slower cooling they would not have been retained, and the steel would have had about the same structure and properties as originally.

Figure 15 is a photograph of a weld made in a piece of firebox

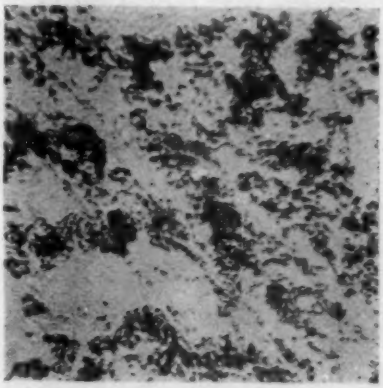


Fig. 18

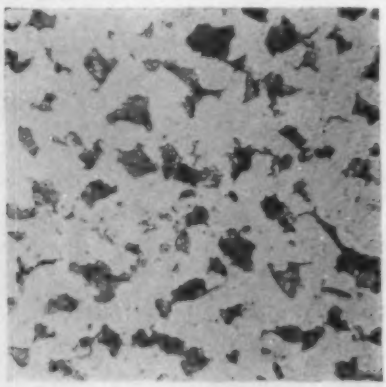


Fig. 19

Fig. 18. Structure of tensile test pieces Nos. 4, 5 and 6 heated to 1500 deg. F. for 10 minutes and cooled in air. The pearlite has just started to dissolve, but the temperature was not sufficient. 430X

Fig. 19. Structure of tensile test pieces Nos. 7, 8 and 9, heated to 1600 deg. F. and cooled in air. The pearlite has been dissolved and has reformed during cooling, leaving an annealed structure. 430X

plate and allowed to cool in the air. The material just along the V has, of course, been fused, and because of this become a steel casting, although, of course, this zone of fusion is very narrow. From this fused zone the temperature gradually decreased until it arrived at the point where it was just above the line in the diagram. At this point the grain is finer than it is anywhere else, even finer than in the original plate.

In order to show the physical effects of welding, I prepared some test pieces of $\frac{3}{8}$-inch boiler plate of the standard dimensions of the A. S. T. M., and heated them to 1400, 1500, 1600 and 1750 degrees F. for fifteen minutes, removed them from the furnace and allowed them to cool in air. Two pieces were also heated with a large torch to approximate welding conditions, the edges being slightly fused. The temperature of these pieces was probably about 2500 degrees F., though no exact measurement was made.

Table I gives the results of the tests of these pieces:

HEAT TREATMENT OF TENSILE TEST PIECES

Specimen Nos.	Temperature	Average Tensile Strength	Yield Point	Per Cent Elongation
13, 14	Not Heated	57,900	36,400	24.8
1, 2, 3	1400° F.	55,200	34,200	27.0
4, 5, 6	1500° F.	55,900	33,600	26.8
7, 8, 9	1600° F.	57,500	38,600	28.2
10, 11, 12	1750° F.	57,100	34,600	28.0
15, 16	approx. 2500° F.	57,000	34,100	26.0

Figures 16 to 21 are photographs of the average structure in each of the above series of test pieces. An endeavor was made to correlate the structures and hence the physical properties of the

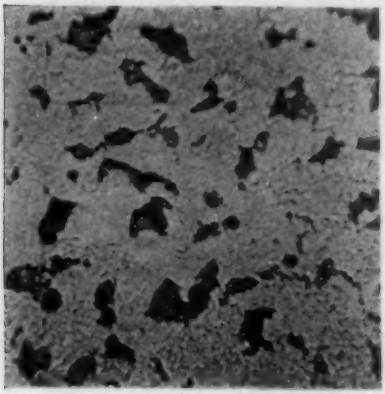


Fig. 20

Fig. 21

Fig. 20. Structure of tensile test pieces Nos. 10, 11, 12 heated to 1750 deg. F. for 10 minutes and cooled in air. The grains are somewhat larger than in Fig. 18 due to the higher temperature. 430X

Fig. 21. Structure of heat treated pieces Nos. 15 and 16. The grains are quite large and angular due to the high temperature. 430X

above tensile test pieces with the structures in a welded plate. Structures corresponding to tensile test pieces 1, 2 and 3 and to 15 and 16 are readily found in welded plate and photographs of them are shown in Figures 22 and 23. The structures of test pieces 7, 8 and 9 and 10, 11 and 12 cannot be found in a welded structure, as the cooling rate in the specimens was not sufficiently rapid to simulate welding. However, in respect to grain size, they correspond to spots between 1 and 2 on Figure 15.

This difference in the microstructure between the different test pieces is accounted for by the difference in maximum temperature. The higher temperatures allow the grains to grow, while the lower ones are just right to get the maximum fineness of grain. Inasmuch as the temperature variation exists in every welded piece, there must be a corresponding variation in physical properties. The increase in ductility at a spot some distance from the weld allows that point to stretch under heavy pressure before the rest

of the material, and as soon as it begins to thin down naturally the resistance becomes less, with the result that final rupture takes place at the point of greatest ductility. This is well shown in Bulletin No. 5 of the American Welding Society, which gives the results of the tests made at the Bureau of Standards in Washington. Tanks XI, page 96, RX6, RX18 and RX19, page 111, and RX20, page 112, show, among others, this stretching and final rupture. Of course, this would only take place in a tank properly welded.

In the case of a brazed tank where the heat is from a much wider flame or source of heat, such as a furnace, it is natural that this

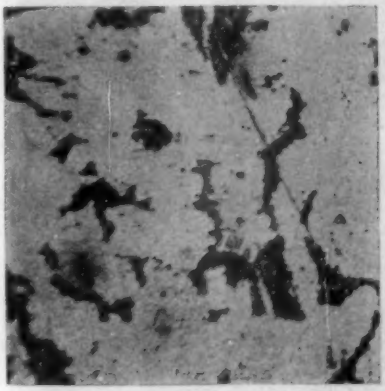


Fig. 22

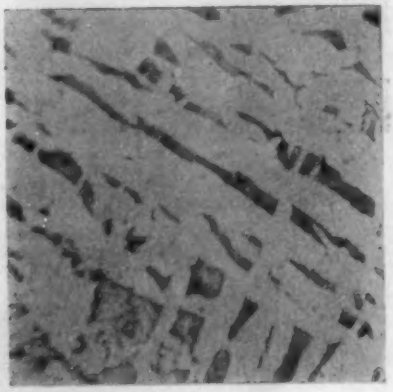


Fig. 23

Fig. 22. Structure of spot 4 on Fig. 15. This is somewhat similar to that in Figs. 17 and 18. 430X

Fig. 23. Structure at spot 3, Fig. 15. This is similar to Fig. 21. 430X

Fig. 24

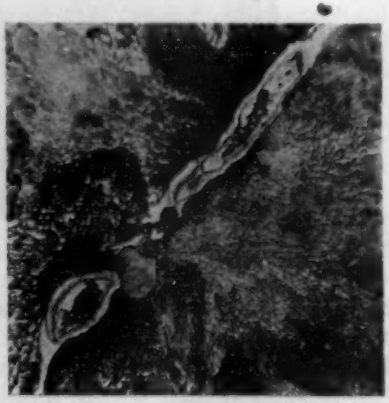


Fig. 25

Fig. 24. View in base metal near weld in steel .70 carbon of poor quality. The impurities have collected at the grain boundaries and weakened the structure. 430X

Fig. 25. View in base metal near weld in tool steel. Here also impurities have been rejected to the grain boundaries. 430X

ductile zone shall be further from the joint, but there is no difference whatever in the action of the heat, and a brazed tank is no stronger than a welded one. With an electric weld the failure will

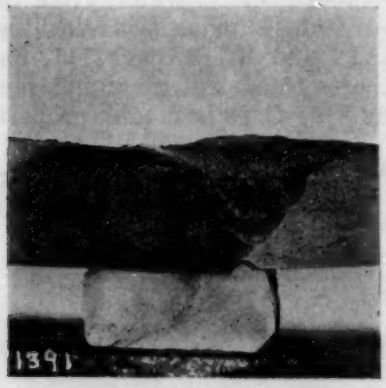


Fig. 26

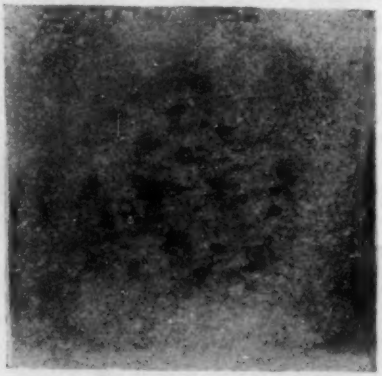


Fig. 28

Fig. 26. Macro view of weld in tool steel. The material on the right by accident was high speed steel. The weld is sound and clean

Fig. 28. Deep etched cross section of a 12 x 12 in. billet that cut with difficulty with the oxyacetylene torch. Each black area represents one or more holes

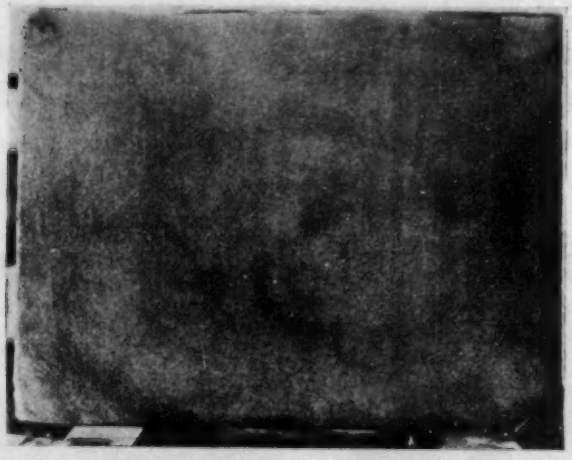


Fig. 27. Deep etched cross section of a 6 x 8 in. billet that cut well with the oxyacetylene torch

occur closer to the V, but again there is no difference except in the location of the ductile zone.

There is a very important thing of which we have said nothing yet. It is in regard to the quality of steel. It has very little to do with the chemical composition or physical properties. It is almost impossible to devise any practical means of determining it, or of putting it in a specification, but it must be taken account of in welding if we want successful results. I have spoken of the re-

jection of impurities to the grain boundaries in a steel casting, and in the fused zone along the V of a weld. If the steel is clean there will be no dirt to go to the grain boundaries. If it is dirty there will be this action with the resultant weakness in and close to the fused zone.

Figure 24 shows what happens just next to the V with a dirty piece of steel. You will notice the line of small particles of dirt which weaken the welded joint. It is therefore necessary, where strength is of importance, to use clean steel. In the case of plate, this can best be done by specifying firebox quality. Next to this comes flange quality. Tank steel has no specification, and is not

Fig. 29

Fig. 30

Fig. 29. An unetched section of steel which is of good quality. There are very few inclusions and those are quite small. 100X

Fig. 30. An unetched section of steel which is of poor quality. There are very few inclusions and those are quite small. 100X

at all suitable because of its wide variation in character and quality for any important welding. Of course, for open tanks or other structures not subjected to great stresses, its cheapness warrants its use.

With regard to the amount of carbon in the steel, the range in firebox plate is from 15 to 25 carbon. These are the specification limits, and we may well consider which is the better material for our purposes. It is ordinary practice to use low carbon steel welding wire. This in the double V weld has a strength of about 50,000 pounds per square inch of plate section. Now, if we have a plate of not over 15 carbon, its tensile strength will not be over 55,000 pounds per square inch, so that the weld will be of about 90 per cent of the strength of the plate with the usual reinforcement. With 25 carbon, on the other hand, the tensile strength of the plate will be about 60,000 pounds per square inch, and the weld will only have a strength of 77 per cent of that of the plate.

In both these cases the strength of the weld governs the design, because it is weaker than the plate, but supposing that we use a

plate of less tensile strength than the weld, say 45,000 pounds, or suppose that we use a weld metal stronger than ordinary low carbon steel wire. Let us take, for example, a plate whose strength is 50,000 pounds, and a wire whose strength in the weld is 55,000, we then have an efficiency of the weld greater than that of the plate, and the plate will always break. It is not important in this case to know the strength of the weld. All that we care about is that it is always stronger than the plate. The point about these figures is that in the cases in which the weld is weaker than the plate, increasing the tensile strength of the plate does not reduce the thickness for a given pressure or load, as the design must be based on the strength of the weld, while in the case in which the weld is stronger than the plate, the strength of the latter governs, and it may be possible to save material, or at least use no more than with high strength plate. To put it another way, a weld of 50 per

Fig. 31

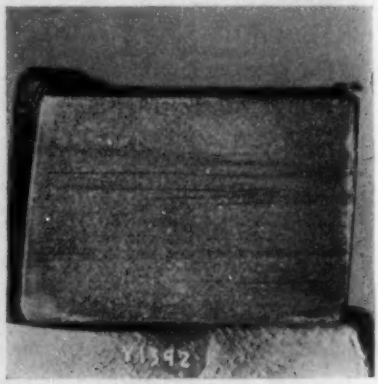


Fig. 32

Fig. 31. View on the cut edge near the bottom of a 6 x 6 in. billet of .45 C steel. The steel has been somewhat carburized. 430X

Fig. 32. Macro photograph of cut edge in ½ in. firebox plates. The cut edge is on the left

cent efficiency in a 100,000 pound plate would require just as much material as a weld of 100 per cent efficiency in 50,000 pound plate.

The higher the carbon in the material the greater the liability of injury from either heating or mechanical working of any kind. The effect of heating tool steel to a high temperature is shown in Figure 25, where the grain boundaries have been burnt by the higher temperature, even in the zone that has not been melted, so that the lower the carbon in the steel we use for welding the better we are off. Therefore, from every point of view, we should use for important work steel of as low carbon content as possible.

This leads us to Figure 26, which shows the effect of welding together two pieces of high carbon steel. The weld is clean and sound, and the union between the steel and the weld is good, but just next the weld the microscope shows that the steel has been

burnt. Such a weld may be satisfactory for some purposes, but it is not possible to get equal strength with the original material. I know of no way by which this burning of high carbon steel can be overcome.

To sum up, we may conclude that (1) the effect of the welding heat on a low carbon steel of good quality is small, but that the effect on high carbon steel is great.

2. That therefore we should use as low carbon steel as is possible for our work.

3. That where we cannot use low carbon steel we must not expect as good results; and that it is useless to attempt to weld tool steel or other steels of high carbon content.

4. That as a matter of economy there is nothing to be gained by the use of high strength steels when ordinary welding wire is used,

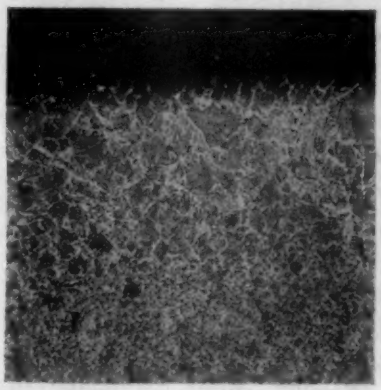


Fig. 33

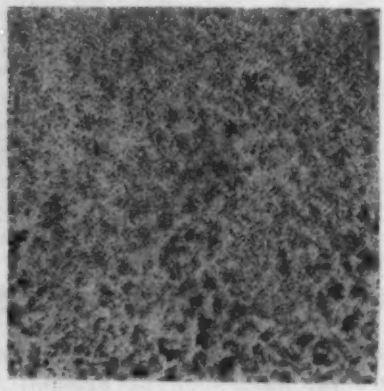


Fig. 34

Fig. 33. View of cut edge of ½ in. firebox plate. The pearlite has been precipitated as a coarser structure than originally. 100X

Fig. 34. View just next to that in Fig. 33. The pearlite has partly dissolved and has been scattered through the zone. 100X

but that there may be economy in using such steels where the weld can be made strong enough by the use of suitable welding wire.

5. That there is a point of maximum ductility and minimum strength at a distance from the weld, depending on the process used, and that this is the point at which rupture occurs with clean steel.

6. That only the best quality of steel, with regard to its cleanness and freedom from impurities, should be used in important work.

There are some very interesting heat effects due to cutting, particularly in heavy sections, and it may be well to start by showing that steel quality is just as important in large pieces, such as billets, as it is in smaller ones, such as plate. Figures 27 and 28 show two large billets, the former of which cut beautifully, while the latter could not be cut smoothly, and required much more time. The

sections were cut and etched and the impurities can be very distinctly seen in the latter case. It has also been found that dirty steel is much more liable to crack when cutting heavy sections than clean steel. In fact, we have found no instances of clean steel cracking when proper practice is followed.

Figure 29 shows the general quality of good steel which does not crack. Figure 30 shows the quality of one piece of steel that did crack. Of course, the trouble from cracking never occurs in ordinary boiler plate while cutting, and even if a piece of heavy steel does crack, we should not always assume that it is not of good

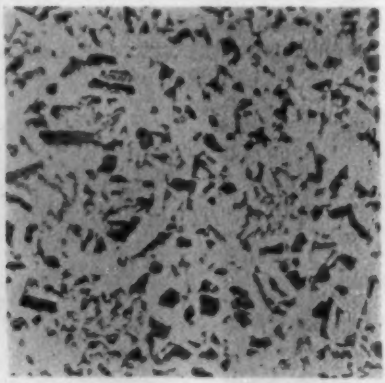


Fig. 35. Original structure of firebox plate before cutting. 100X

quality, because there may be other causes, such as improper cutting practice, lack of preheating, or some other deficiency that may have something to do with it. It is, of course, also true that all dirty steel does not crack while being cut. There is probably considerable difference in the effect on the character of steel of different kinds of impurities. Oxides of the various elements are probably more dangerous than manganese sulphide or other foreign matter.

Another effect of the heat, especially in cutting heavy pieces, is that the cut edge is carburized to an appreciable depth. It is always the case that by mere heating of a piece of steel some of the carbon is removed from the surfaces exposed to the heat. The action of the cutting flame is different in that for a short distance from the cut the steel is heated to an exceedingly high temperature, a very thin film of it being even melted. The steel from the kerf has the carbon in it oxidized to carbon monoxide, which is the active element in case hardening, so that the intensely hot steel eagerly absorbs the carbon from the carbon monoxide. Of course, this zone is very thin, maybe .006 to .007 inch thick, but at the extreme edge there are frequently projections containing as much as 5 or 6 per cent carbon. The appearance of the cut edge on .50 carbon steel is shown in Figure 31.

It may be of interest to state that the carbon does not come from the flames of the cutting torch, as material that contains no carbon shows no evidence of carburization.

The cutting of low carbon material causes very little carburization of the cut edge, especially in thin material like boiler plate. This is both because of the low carbon content and because of the thinness of the material, which does not permit the carburizing action to occur. In other words, the amount of carbon monoxide is small and most of it is blown through the kerf, and so has no time to act. Figures 32, 33, 34 and 35 are photographs of a cut edge in ½-inch steel and the heat affected metal.

Another effect of the heat during both welding and cutting is the oxidation of the metal. Iron rusts or oxidizes slowly at ordinary temperature, but at the high temperatures of welding or cutting oxidation is not only rapid, but much greater. This oxide is soluble to some extent in the melted metal, but is not soluble in the cold metal, so that it crystallizes out during the freezing and weakens the weld. Also, when a cut is welded, a large amount of the oxide left on the surface by the cutting is included in the weld to its detriment. Therefore all precautions should be taken to avoid these defects, and in all cases the surface of the cut edge should be thoroughly removed, preferably by grinding or chipping off a small amount, this leaving the surface perfectly clean for welding.

Much inferior welding is caused by the presence of this oxide. When welding wires that spark freely are used, more or less of the sparks, which are iron burnt to oxide, fly on to the surface of the V ahead of the weld. This oxide melts at a lower temperature than the steel, and is liable to deceive the welder, who thinks he has the steel melted, but in reality has only succeeded in fusing the oxide which coats the surface of the V. Again, in heavy welding, where it is not possible to keep all of the top of the V fused at one time, the red hot surface becomes heavily scaled with oxide, and when it is reheated in order to add more welding rod, the scale is dissolved in the melted metal, and, as explained above, weakens the weld, so that, particularly for heavy welding, welding rod should contain such elements as will combine with this oxide and make a fusible slag, which will remain on the surface and not be included in the weld.

Welding of Non-Ferrous and Special Metals by the Resistance Welding Process*

H. A. WOOFTER†

In accordance with a request from the Resistance Welding Research Committee of the American Bureau of Welding sometime ago to make a report on the Welding of Non-ferrous and Special Metals by means of the Resistance Process, I wish to submit the information given below:

The welding of non-ferrous metals is of recent origin. Up to about two centuries ago, soft charcoal iron was practically the only metal that could be welded by the blacksmith, although some of the precious metals, such as gold and silver, had been welded by the blow torch process. With the advent of resistance welding in 1885, it immediately became possible to weld any and all of the non-ferrous group of metals with the exception of tin. Also it became possible to weld any or all of the ferrous group of metals together, or any of the ferrous to any of the non-ferrous group with the exception of tin. One other partial exception should be made in the case of cast iron. One piece of cast iron can be welded on to steel or practically any other metal, but it has not yet been possible to successfully weld two pieces of cast iron together by the resistance process.

With the advent of Resistance Welding, the possibilities of the art of metal working were multiplied a thousand fold, because many metals and alloys that are with difficulty welded by other processes can now readily be welded. For instance, stellite and chromium steel are two notable examples of metals or alloys that can be welded successfully only by this new process. So recently as 1910, it was considered impossible to weld by the resistance process aluminum or any of its derivatives. Now aluminum and one of its products, duralumin, are among the most easily welded of metals. Many of the non-ferrous and special metals are subject to enormous oxidation while being heated, and the longer or slower the process of heating, the greater the oxidation.

Aluminum

Everyone knows from observing the photographer's flashlight or the making of a thermit weld, the enormous affinity of aluminum for oxygen. It is practically explosively sounder heat. Now what takes place if this metal is welded by any process requiring a considerable lapse of time? Oxidation would, of course, play the greatest part, and this oxidation releases or produces a product

*Prepared for the Resistance Welding Committee of the American Bureau of Welding and constitutes a review of the present state of the art of welding of non-ferrous and special metals by the resistance welding process.

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known as Alumina, which does not melt until it reaches 5000 deg. Fahr. Now, since aluminum itself melts at around 1218 deg., it can easily be seen that a granular weld would be produced, owing to the particles of unmelted alumina being surrounded by this aluminum, and the weld breaks with a fracture similar to that of sandy cement. Now suppose instead of using a considerable length of time to make an aluminum weld, the weld is made practically instantaneously as in the case of the Resistance Method. In this case, there is no time for oxidation, and the blowout effect of the large secondary current acts in the nature of a blowout coil, further keeping away the oxygen. This kind of weld shows a clear break the same as any other part of the metal, with no traces of alumina.

Brass

The ordinary commercial grade of this metal usually analyzes about 34 per cent of zinc and 66 per cent of copper. Now suppose it were attempted to weld this metal by means of a forge or some other process requiring a considerable element of time. When the heated parts reach about 787 deg., which is the melting point of zinc, the zinc would volatilize and disappear from the vicinity of the weld. Then as the temperature further increased to approximately 1981 deg., which is the melting point of copper, there would be no metal except the copper left at the welding point, and this copper has undergone certain distinct chemical changes which will be described a little later on in this article, and the result is a spongy, porous weld lacking the strength of the original brass and even weaker than the original copper. Now if this weld is made practically instantaneously, there is a sharp report like that of a pistol, and the weld is completed without time for volatilization of the zinc, nor for the oxidation, nor sulphidization of the copper. Some manufacturers are using the great possibility of the resistance process in upsetting brass and bronze rods, as for instance, in the case of gate valve stems. It was formerly necessary to turn down a large bar in order to make the thrust collar on the valve stem. Since some of these stems are ten feet long, one can see the enormous loss of labor and material that occurred when making these gate valve stems by the old process. Now, however, the stem is placed in a resistance welder with the point to be heated between the platens, current is turned on, and at the first showing of pink color the platens are pushed up, making an upset from which the thrust collar is turned, thus saving any machining down along any other parts of the stem. These upsets are made without breaking the skin of the original rod, and when one of these upsets is cut in two, polished, etched and micro-photographed, the structure of the metal is practically the same as at any other point of the rod, except that its density has been somewhat increased due to the mechanical pressure applied, and this is considered an added advantage rather than a detriment.

Copper

Now let us consider the changes that take place when welding copper if it is heated by means of a forge or torch or any process requiring considerable lapse of time. Hot copper having an enormous affinity for oxygen, absorbs it from the air and forms cuprous and cupric oxide; also if the copper contains sulphur, and practically all copper does, two distinct sulphides will be formed —cuprous and cupric sulphide. In order to minimize the formation of these oxides and sulphides, it is necessary to use enveloping fluxes, which would combine the oxides and sulphides and to keep them out of the weld. These fluxes do improve matters from the standpoint of the oxygen which was being absorbed from the atmosphere, but do not help the forming of sulphides which come from the substances within the metal itself. Furthermore, the weld will absorb a certain amount of the fluxes, which is usually phosphorus, thus greatly hardening the weld and at the same time reducing its electrical conductivity. Copper rods welded by this process can not be drawn through reducing dies owing to the hardness of the weld, and in some cases could not even be forged or rolled without breaking, and the break usually shows red short structure.

In the Resistance Process, the work is butted together in the welder under mechanical pressure, and the current thrown on. There is a loud report like the discharge of a gun, the softened metal is instantly pushed up by the pre-established pressure, and the weld is completed in about one-tenth to two-tenths seconds of time. Welds made in this manner can be drawn through reducing dies, can be forged or rolled, and there is no reduction whatsoever in the electrical conductivity.

Duralumin

If it is attempted to weld this metal by any slow process of heating, practically the same chemical and physical changes take place as in the welding of aluminum. Welds so made must always be annealed for a period of from five to seven hours to prevent their deterioration and failure due to hydroscopic absorption either from the atmosphere itself or when exposed to moisture. With the Resistance Method, however, the weld is made practically instantly, and it is not necessary to anneal the weld unless the very maximum strength of the metal is required. By annealing resistance welds in duralumin a tensile strength is secured in a ratio of 61:55 over that of the un-annealed weld. No deterioration takes place in the un-annealed weld due to the hydroscopic absorption, since the mechanical pressure applied at the instant of welding solidifies or condenses the metal, whereas in other processes, the weld is spongy, leaving minute pores for the absorbing and holding of moisture.

Monel Metal

Monel Metal is welded very similarly to ordinary steel as fa. as projection, mechanical pressure and time are concerned, but it takes about 25% more power to weld it than the same size of steel. This metal lends itself very readily to seam welding, thus making it a very valuable metal for ice cream and milk containers, battery jars, etc., since the metal is impervious to rust and is not acted upon by any except the strongest acids.

Special Metals

Several special metals are welded very readily by the resistance process, as for instance, stainless steel, which is made by alloying from 16 per cent to 20 per cent of chromium with the steel. If it is attempted to weld this metal by any process requiring considerable time, porocity always appears due to the different temperatures of melting of chromium and steel. However, when welded instantly, it makes a beautiful weld. It is now being used for the stems of automobile valves, and is welded on to the cast iron head by a resistance process known as the Pressure Contact Weld. Many other special metals too numerous to mention can be easily welded by the Resistance Process. It is only necessary to procure a specimen of the metal large enough to make a few experimental welds in order to determine the best setup for the particular job at hand.

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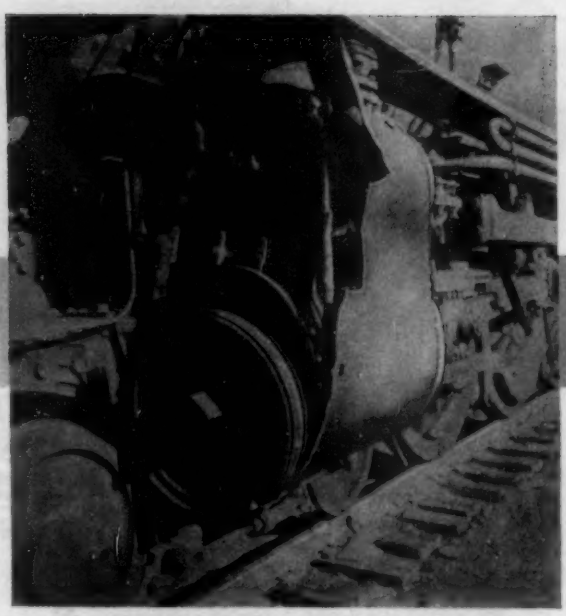

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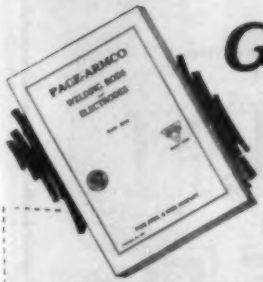

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